

ALTERNATIVE AGRICULTURAL PRODUCTS RESEARCH ACT OF 1987

HEARING

BEFORE THE

COMMITTEE ON AGRICULTURE, NUTRITION, AND FORESTRY UNITED STATES SENATE

ONE HUNDREDTH CONGRESS

FIRST SESSION

ON

S. 970

A BILL TO AUTHORIZE A RESEARCH PROGRAM FOR THE MODIFICATION OF PLANTS FOCUSING ON THE DEVELOPMENT AND PRODUCTION OF NEW MARKETABLE INDUSTRIAL AND COMMERCIAL PRODUCTS, AND FOR OTHER PURPOSES

MAY 15, 1987

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ALTERNATIVE AGRICULTURAL PRODUCTS RESEARCH ACT OF 1987

FRIDAY, MAY 15, 1987

U.S. SENATE,
COMMITTEE ON AGRICULTURE, NUTRITION, AND FORESTRY,
Washington, DC.

The committee met, pursuant to notice, at 9 a.m., in room 332, Russell Senate Office Building, Hon. Tom Harkin, presiding.

Present or submitting a statement: Senators Harkin, Daschle, Lugar, and Bond.

STATEMENT OF HON. TOM HARKIN, A U.S. SENATOR FROM IOWA

Senator HARKIN [presiding]. The Senate Committee on Agriculture, Nutrition, and Forestry will come to order.

I am pleased today to hold these hearings on S. 970,¹ the Alternative Agricultural Products Research Act of 1987. I would like to thank my colleagues Senators Leahy, Lugar, Glenn, and Burdick for their leadership in this area and their cosponsorship of this measure.

For some time my colleagues and I have been increasingly interested in stimulating diversification in the agricultural economy. It is the intent of this act to help this process through a substantial accelerated R&D program.

We are all aware of the fact that our agricultural factory, with its level of technology, superior natural resource base, and the amazingly productive American farmer, can outproduce most of the rest of the world combined. Such a reality is both a blessing and a curse. The blessing, of course, is that we can meet all of our Nation's food and fiber needs with ease and at a low cost. The curse results from the fact that we can, and do, overproduce. The result of this overproduction has been the lowering of the value of both our commodities and our land, and of course the bankruptcy of thousands of our family farmers.

In the long term, the agricultural problem is more than a question of production levels or of export markets. It is also a problem of insufficient diversification. We lack diversification in many agricultural areas of the country where only a few commodities are produced. We also lack diversification in the range of end uses for which our agricultural feedstocks might be used.

The result is, that as the capacity to produce traditional commodities such as corn or soybeans increases, our farmers face three

¹ See p. 147 for a reprint of S. 970.

choices. First, there can be greater and ever greater levels of production in excess of demand creating lower prices that will not cover the costs of production. Second, we can leave part of our capacity idle. Third, we can find new things to do with our capacity. Now, this third way is the best solution that will take many years to implement. This bill moves us in that direction starting now.

Starting now, we must develop new plants capable of producing new industrial and commercial products that can compete for land, labor, and capital. We need our existing commodities bioengineered so that the range of new products capable of being produced can be expanded several fold.

I can see a day when new plants will be designed for specific end uses, or process conditions. I believe it is possible with the mapping of genetic structure of corn, wheat, soybeans, and other feedstocks, that we will be able to bioengineer new industrial oils, new proteins, and new chemicals. All of this diversification is necessary as a precursor to a competitive agricultural system.

The days of simple basic industries with proven technology being successful over the long term are over. The steel industry and the auto industry make this point all too clear. We need new technology and new knowledge to continue the evolution of our Nation's largest industry—agriculture—so that its full potential can be realized.

The development of this new technology for agriculture will require new knowledge. Systematic development of new plants and the modification of existing plants to produce new products is well beyond the current state of the art. What is needed therefore, is a large scale multiyear research program directed toward the ultimate development of a more diverse agricultural system.

I realize that many of the fundamental questions about the biology of plants remain unanswered. I also realize that this fact adds to the risk associated with this undertaking. Nonetheless, we must proceed with the effort and deal with our knowledge gaps along the way.

History has shown that research with a purpose, even with significant unanswered questions, can be successful. In 1941 the Nation launched an effort to develop radar. There were many fundamental unanswered questions. These were addressed as a part of the quest to develop radar. Likewise, new plants can only be developed after we increase our fundamental knowledge. That knowledge, however, must be linked to a purpose. In this case, that purpose is new plants and new products: a new agriculture.

To get the process of R&D underway, we are planning a major research initiative of \$75 million per year for the next 20 years. That amounts to about \$1.5 billion. The amount of funding suggests the scope of the problems to be tackled. The 20 years implies the need for a sustained effort over a long period of time sufficient to study and process engineer a number of new agricultural feedstocks.

It is my feeling that it is time to greatly expand plant biotechnology and bioprocessing research. We are prepared to do that and look forward to launching this program in this Congress.

Today we have a series of witnesses before the Senate Agriculture Committee who are experts in this area, many of whom have

had a long history of involvement in the type of things that we are talking about in this legislation.

Senator Glenn was to be here. He is tied up so we will move ahead because we do have a vote coming up at 10 o'clock this morning. So, first, I would like to welcome back to the committee Dr. Orville Bentley, Assistant Secretary for Science and Education from the U.S. Department of Agriculture, and David Kingsbury, Assistant Director for Biological, Behavioral, and Social Sciences of the National Science Foundation.

Again, both of you, welcome to the committee. Dr. Bentley, it is good to see you again. The entirety of your prepared statement will be made a part of the record and please proceed as you so desire.

STATEMENT OF DR. ORVILLE G. BENTLEY, ASSISTANT SECRETARY, SCIENCE AND EDUCATION, U.S. DEPARTMENT OF AGRICULTURE

Dr. BENTLEY. Thank you, Mr. Chairman.¹

I quote: "One way to expand the farmer's market is to develop industrial uses for farm products." These words were contained in an introduction to a chapter entitled "The Industrial Market for Farm Products" in the 1940 Yearbook of Agriculture.

Another quote: "Why do we not grow a greater variety of crops, particularly to provide raw materials for industry?" This question was posed in the 1963 Yearbook of Agriculture in the chapter devoted to "The Search for New Crops."

Mr. Chairman, I welcome the opportunity to appear today before this committee to testify on S. 970, the act that you referred to as the Alternative Agricultural Products Research Act of 1987.

I opened with the quotes from the past because I think we should recognize the fact that American agriculture has long been aware of the potential which exists for the creation of industrial and commercial products from its crops.

In 1938, Congress authorized the creation of four regional agricultural laboratories which would be devoted to product research and development. These Centers, operated by the Agricultural Research Service, and located at Peoria, IL; Wyndmoor, PA; Albany, CA; and New Orleans, LA, have been involved in the research and development which led to many of the new products derived from agriculture, as well as for products used in the production of our food and fiber.

The present ARS budget of approximately \$42 million for utilization research is about equally divided between the development of new and improved food and feed products and of nonfood derivatives from surplus commodities. Target raw materials for industrial uses are starch, vegetable oil, tallow, and cotton fiber. Target non-food markets include detergents, paint, pharmaceuticals, cosmetic industries, as well as additive markets for plastics, lubricant oils, textiles, leather, paper, and construction industries.

Use of the new technologies, such as bioconversion and enzyme engineering are critical to the development of an economic process product for those specialties in bulk chemical markets. Other op-

¹ See p. 57 for the prepared statement of Dr. Bentley.

portunities for starch utilization include the development of biodegradable films for agricultural production and controlled-release formulation for pesticides encapsulation.

Additional research is being expanded to improve the current market position of cotton by improving fiber quality and developing unique products such as thermal sensitive fabrics and nonwoven materials.

Postharvest research conducted in a State agricultural experiment station include a wide array of projects, among which are nonfood byproducts of food crops; fuel crops; nonfood animal products; quality maintenance; chemical industrial crops; natural fiber textiles; and some market development activities.

Research in the nonfood areas was funded at approximately \$7 million in 1985 with the States investing about \$40 million on research to expand the demand for food products. Thus, this effort includes research on new and improved food products and quality enhancement.

In addition, the Forest Service is maintaining a good deal of research in nonfood crop utilization and they have committed about \$8 million in 1985 for research at Forestry schools, and \$14.5 million by the U.S. Forest Service.

In my statement I refer to a news release on the development of the use of starch in films from the Peoria laboratory, which we think is a very exciting development.

In late 1984, then-Secretary of Agriculture John R. Block sponsored a "Secretary's Challenge Forum on New Uses for Farm and Forest Products." As an outgrowth of that forum, we proposed and Congress provided funds for a \$10 million initiative to develop new uses for a variety of crops and livestock surpluses, and to develop new products for export. I am pleased to report that this program, funded in 1987, is underway at a number of ARS locations. Raw materials under investigation include starch, vegetable oils, tallow, and cotton fiber—the products that I referred to earlier in the statement about the function of our laboratories. This work is carried on in cooperation with industry and in cooperation with university scientists throughout the country.

A public-private task force was also created to carefully examine the issues of finding new uses for farm and forest products, with particular emphasis being given to industrial uses. That task force, comprised of private sector, university, and Federal members, has completed its work and will be issuing a final report within the next few weeks.

Mr. Chairman, I have presented this brief background to indicate that the Department of Agriculture supports research and development to find new uses for farm and forest products. As I read the purpose of S. 970, to authorize a research program for the modification of plans and associated research, in order to develop and produce marketable products other than traditional food and fiber products, I must conclude that the Department presently has sufficient authority to achieve that purpose.

My comments should not be construed as suggestive that we are against the concept of new uses research which is contained in this bill. To the contrary, as I have said, the Department is actively engaged in such research and development projects. The administra-

tion is, however, opposed to the enactment of this bill because it substantially would duplicate present authorities for research. The bill would also authorize a \$75 million annual appropriation for each of the next 20 years. Again, I must point out that present authorities are sufficient to allow the Congress to appropriate moneys for the type of research called for in this bill.

Further, the bill would establish a New Products Research Board to advise the Secretary on policies and specific research proposals for new uses. This Board would unnecessarily duplicate functions already carried out by other committees, such as the Joint Council on Food and Agricultural Sciences.

I do want to commend the sponsors of this bill and other Members of the Congress who have expressed interest and provided support to the USDA's efforts to find new uses for farm and forest products. I would certainly be remiss if I did not call attention to the similar work which is being conducted by our Nation's land-grant universities and colleges, and by the forest products laboratories.

I am advised that later today you will be hearing from representatives from the university research community, and I am sure they will be pleased to inform the members of the committee of their activities.

I have with me today Dr. William Tallent of the Agricultural Research Service, and Dr. Paul O'Connell of the Cooperative State Research Service. We will be available to answer questions on any particular aspects of our current program if the committee would so desire.

We thank you for giving us an opportunity to speak on the bill and to indicate our concern and interest in research and development of all additional uses for farm products, but especially in the nonfood use area.

Thank you.

Senator HARKIN. Secretary Bentley, thank you very much for that fine statement.

Again, I want to add my praise to you for initiating some, and maintaining all, the programs that you have talked about. I know of your long history in this area and you are to be commended for that. I would like to discuss with you, after we get through your statement, some of the areas that we might cooperate on.

I am going to diverge here and call upon my esteemed colleague from Indiana, Senator Lugar, for any opening statement that he might have.

STATEMENT OF HON. RICHARD G. LUGAR, A U.S. SENATOR FROM INDIANA

Senator LUGAR. I thank the chairman, and it is good to hear you, Dr. Bentley, and I appreciate this opportunity for the Agriculture Committee to receive testimony on S. 970, the Alternative Agricultural Products Research Act of 1987.

Members of this committee are acutely aware of the surplus problems plaguing American agriculture. These surpluses are an enormous burden on both farmers and taxpayers. A report prepared by the 99th Congress in the Office of Technology Assessment

suggests our capacity to produce will not level off in the next decades. To the contrary, new technologies, such as the hybrid wheat and growth hormones in dairy cattle will likely lead to even greater surpluses.

Some have suggested that the only solution to the problem is to export our surpluses. Indeed, we must be competitive in international markets and continue to strive for an increased market share.

However, increased exports is not the entire solution to our present ability to overproduce. I believe we must begin to more aggressively develop alternative markets for American farm products. In order to increase demand for farm products both at home and abroad we should begin research and development on products other than traditional food and fiber, and that is the purpose as I see it, of S. 970.

This bill provides the mechanism and the criteria to fund long-term research projects designed to develop marketable industrial or commercial products other than traditional food and fiber. These new products could be developed either by the modification of a plant or the modification of the product of a plant.

Mr. Chairman, I appreciate your cooperation and that of your staff in designing this bill. I want to commend also the cooperation of the distinguished chairman of our committee, Senator Leahy, and Senator Glenn, who will be our witness today. I appreciate, as you do, that he has agreed to testify on S. 970.

Senator Glenn, I would point out, and I have worked together on similar bills in the past and his counsel in this area has been very valuable. I look forward to hearing his testimony today.

I believe the topic of the hearing is important to the future of American agriculture and I look forward to hearing the testimony of all of today's witnesses.

Mr. Chairman, I would point with some parochial pride to Dr. B.R. Baumgardt, the director of the Indiana Agricultural Experiment Station at Purdue University, whose testimony I will especially appreciate.

Thank you very much.

Senator HARKIN. Thank you very much, Senator Lugar.

I want to welcome Senator Glenn to the hearing. Senator Glenn, you have long been an advocate of research aimed toward diversification of the products that we can produce from agricultural crops and along with Senator Lugar, on the 1985 farm bill, your leadership was responsible for section 1436(b) which provides for the expenditure of money for research and development of industrial, new, and value-added farm products. The two of you have been pioneers in this area. We certainly welcome your support and your input to take this concept you have started to develop and move it along.

So, Senator Glenn, again, welcome to the committee. Your prepared statement will be made a part of the record in its entirety. Please proceed as you desire.¹

¹ See p. 59 for the prepared statement of Senator Glenn.

STATEMENT OF HON. JOHN GLENN, A U.S. SENATOR FROM OHIO

Senator GLENN. Thank you very much. My remarks will not be lengthy, Mr. Chairman.

I do appreciate very much the opportunity to appear again on this subject. I also want to thank you for providing the opportunity for Dr. David Zartman, a professor from Ohio State University, to present testimony on the good work being done at OSU regarding new uses research.

The 1980's have not been kind to U.S. agriculture. Prices have declined, forcing income lower. Land values have declined, forcing thousands of farmers out of business. The chairman and I have talked about this, about the impact on Iowa where it has had a particularly bad impact on the whole agricultural community and on my home State of Ohio, also.

Unfortunately, it does not look like things are going to improve in the near future. As a result we must provide short-term aid to address our current problems, as well as devise a long-term strategy which will return profit to agriculture. That is primarily what I wanted to briefly talk about this morning.

Prosperity on the farm occurs when the demand for agricultural commodities is in balance with the supply. In the mid-1950's an expanding export market absorbed the increasing supply of commodities produced by U.S. farmers. While not every year was profitable, on balance, the period between 1955 and 1980 was one of acceptable income for the farm sector as a whole. I am sure we would find a lot of individual farmers arguing with that statement, but overall I think that is a fair statement.

Since 1981 farm exports have declined from \$44 billion to \$26 billion in 1986. During this same period domestic demand for food has increased, but only at the relatively slow rate of population growth. Extension of these trends yields little but a sobering conclusion, and that is that traditional demand outlets—food outlets primarily—show little promise of utilizing the current surpluses in restoring prosperity to American farm families.

Even the possibility that this prediction may be accurate should challenge us to develop bold, new programs which look to the future while embracing the lesson from history that farm prosperity is led by demand. That is why I strongly support—very, very strongly support—the goals of this legislation that we are involved with here.

As you already mentioned, and Senator Lugar mentioned, we introduced similar legislation in the 99th Congress that was incorporated in the 1985 farm bill. This legislation builds on that law, and I encourage that very much. I believe that new uses research—non-food uses—is just such a commonsense approach to the bin-busting surpluses facing us and I just do not see any other way to go.

These new uses for farm and forest products are not far-off fantasies that will take generations to develop. Right now, cornstarch is used not just in producing alcohol, but also in manufacturing paper products, building materials, textiles, and adhesives.

We have just scratched the surface in this area. Many petrochemicals can be made from carbohydrates contained in food and feed grains. However, more efficient manufacturing processes need

to be developed. Even greater potential lies in developing new chemicals and other products that utilize the desirable properties of starch and cellulose.

New uses research encourages the application of basic research in biology, chemistry, and physics to develop new uses for farm and forest products. We are doing some limited research at USDA and in some of the land-grant colleges and private industry, but the amount spent is minimal. Let me give you an example. In fiscal year 1987 we had a total Agricultural Research Service budget of \$510 million. Now, how much of that do we suppose was spent on nonfood uses instead of production? \$6 million out of \$510 million. \$6 million. I think that is preposterous.

Expenditures on new nonfood uses of food products pales beside the money being spent on production research, and that has historically been what we have spent money on. Because we've seen a hungry world out there we encouraged farmers to produce more, we wanted to do more in that area, and so everything has gone into the production side.

We have been good at this. When I was a kid, good corn production back home was around 45 to 48 bushels an acre, for corn, on good farmland. This is not the scrubland off in the rocky hills or something, this was good farmland. It was around 45 or 48 bushels an acre.

Last year I am told our average in Ohio on good farmland was 135 bushels an acre. We are good at production because we have done such a good job of research. This country was built on research, and nowhere has that been more evident than in the area of agricultural research.

Historically emphasis has been on the production side. Just a few years ago we were encouraging people to plant fence row to fence row. That was the word, fence row to fence row, get everything in production because the world demand was going to be out there.

Well, the world demand is not quite what it was predicted to be and now we have production that drives prices down, ruins farm economy, and at the same time last year we put only \$6 million in the ARS budget into nonfood research.

This country got to be what it is because of two things: education and research. We educated people and then we poured more back into basic research than any nation in the history of this world and we learned the new things first and we put it to work.

I helped dedicate an ethanol plant in Southpoint, OH. Its capacity is to use 24 million bushels of Ohio corn every year, but now, of course, the price of that is still up enough that it is not really competitive with gasoline yet. Maybe a little more research in that area might help make that a viable alternative, and all the other areas here that I want to see us do research in.

I would personally like to see us getting up to one-fourth or one-half of our agricultural research being done in new nonfood uses.

Now, I know the Department of Agriculture does a great job. They have a lot of fine people, but I hope this committee can play a major role in breaking them out of these traditions of the past that just keep going and going and going. Nobody wants to break out of the mold, nobody wants to destroy jobs in the production research

area, but somebody has got to shake them out of the lethargy and get going on new nonfood uses research.

They could take the initiative on it if they wanted to, but they have not, and that is where I believe this committee can play a vital role in revitalizing American agriculture.

We can have our farms producing things that go into cellulose or wallboard or automobile bodies or whatever if we do the research to learn how to convert these things over, and so that is what this is all about.

Senate bill 970 does not offer a short-term solution. I am not saying this is going to be something that will help us out next year on the farm, but it is part of a long-term strategy to return profit to agriculture and to create the base for a third golden age of agriculture.

I think such a forward looking strategy is as vital as the key to renewing America's agricultural prosperity and restoring farmers' confidence in the future, so I look forward to that better future for American agriculture.

I want to work with you as closely as we can in shaping this and I hope you can play a major role in seeing that not just \$6 million next year, for heaven sakes, goes into nonfood uses. That will just about buy the blueprint paper and keep the doors open. I would like to see us converting major parts of the ARS research budget.

As I have stated, I would like to convert 25 to 50 percent of the ARS research budget so we don't keep on filling the bins and doing more and more production, so we can store it out under tarps along the railroad siding someplace. This is about as dingaling a policy as I can think of, so I feel very strongly about this.

Thank you. Outside of that——

[Laughter.]

Senator HARKIN. Senator Glenn, thank you very much for your excellent statement. I remember you bringing this to my attention a year and a half ago and when you told me at that time how much they were spending in this area I was amazed. Of course, looking at it further proved that you were absolutely right.

Senator GLENN. Mr. Chairman, when we first got into this thing and the figures were brought to me, I thought somebody had made a mistake on this somewhere because it could not be that low, surely people were looking at the future better than that.

Yet, we got into it, we double checked the figures—this has been back almost 2 years ago now—we checked with Senator Lugar, who was chairman of the committee at that time, and they researched the figures again, we got back together again, and sure enough, the figures were correct. I just could not believe that we are going down this road this far without somebody having gotten over into this new nonfood uses that I see as being the future of agriculture to a large extent.

Senator HARKIN. I could not agree with you more when you mentioned the coming golden age of agriculture. You know, there have been different golden ages of agriculture, when we first got the mould-board plow, and then when we went from the horse to the tractor, and then when we developed our hybrids of corn. Each of these events brought along a golden age, and I think this one is coming.

When, through molecular or genetic engineering, we can develop these new uses, we will bring a golden age to agriculture that will overshadow all of those that ever came in the past. Like you say, it is going to take a long time and we have got to get started on it. These things do not happen overnight.

Senator GLENN. Right.

Senator HARKIN. I just could not agree with you more. I only have one question, Senator Glenn, that I wanted to bounce off of you.

It seems that for a lot of companies—obviously, they are in business to make a profit—doing basic research that may not be applicable for a long period of time is something that they may not be that interested in. They are looking for things like, perhaps a new hybrid that may be drought resistant or pest resistant, or something in the next cycle that they can develop. There seems to be this gap for long-term research, from the basic research to actually getting a product that can be marketed.

Now, we have not done much of that. Since I have talked to you about this in the past I began looking at some other countries and what they are doing and they do indeed have what I guess I might call "applied research" programs. They have basic research and applied research. Then they go to the private companies and say, we have developed it this far. The companies say, well, now we can do something with it, now we can market it.

Do you have any thoughts along that line about how we can get a better developed system of applied research to build on the basic research? I do not have the answers but I am searching for that.

Senator GLENN. Mr. Chairman, I think you put your finger on a very key element, a very key part of this. The way our business and our big business, including agribusiness has developed in this country. The average CEO—chief executive officer—is not like those in other countries—Japan, or Europe, even—where the director of the company—CEO—is probably in for a 12-, 15-, or maybe a 20-year term.

In this country it is not that way. We are shorter fused in this country. We have people on for 3 to 5 years. They have got to produce a bottom line profit or they are out, so they are looking for the short term type investment that is going to hit the bottom line by the end of next year. But that is not what we are talking about here.

Fortunately, we have had a few companies in other industrial areas that have not taken that view of things. They have taken a long-term view. We have the example of Bell Labs, Du Pont, IBM, Monsanto, and 3M. I think in the agriculture area probably Archer Daniel Midland, some people like that that have taken a longer term view of things and willing to put money into some areas of research and stick with it for a period of time and see that once that research comes to fruition that it is then transferred into the marketplace, and bless them for doing that.

The administration in other industrial areas keeps telling us all the time, if research is worth doing, private industry will do it. That is absolute flat nonsense. It is not true. All you have to do is look at the track record out there in industry to know that that is not true.

Our CEO's are the 3- to 5-year bottom line types. Now the Government, it seems to me, has to fill in in this interim period where we have research and we want to convert it over. We want to convert it over and we may need some Government support to do that in the first stages. Do not let it become entrenched where Government runs it. We need that kind of a gap filled.

I am working on legislation right now, in the Governmental Affairs Committee that I chair, to convert some industrial research into common everyday use. We are talking about the reorganization of the Department of Commerce to make it a Department of Industry and Technology. One of the key parts to that is to take this technology that comes under their banner and provide a means of taking that research and making that interface with what we're talking about here.

Now, I think something like that is what is needed in agriculture. Agriculture has just as much inertia against getting new developments into everyday use as any of our other major industries, and this industry of agriculture is 22 or 23 percent of our national GNP. Not just the farms themselves, but all the farm production. I think that around a quarter of our national economy depends on this, and so that transfer or research that we are talking about here, once it is made, is a very vital part of this.

I do not have the answer to it. We are grappling with it over in the other committee as far as industrial research and how you transfer that over, but I think maybe we could work together on some of these things because it is exactly the same problem.

Senator HARKIN. I just want you to know I appreciate you working with us on this. Our staffs have worked together and we look forward to continuing that.

Senator LUGAR.

Senator LUGAR. I have no questions. I just commend the Senator. It is good to hear his vigorous testimony again this morning.

Senator HARKIN. Senator Bond.

**STATEMENT OF HON. CHRISTOPHER S. "KIT" BOND, A U.S.
SENATOR FROM MISSOURI**

Senator BOND. Thank you very much, Mr. Chairman.

I am sorry I came in late, Senator Glenn. I will look forward to seeing the full text of your statement.

Mr. Chairman, I recognize the points that you have made, and Senator Glenn has made so strongly, that we need to do a better job in research, and I would concur that there is a role for Government to play.

I might just mention to you for your information some initiatives that we have undertaken in the 1980's in the State of Missouri that attempt to bridge this gap between research in academia and the practical application.

The Missouri General Assembly, at my suggestion, in 1982 adopted a Higher Education Research Assistance Act. It was passed by the general assembly without a dissenting vote in either House, which makes you immediately suspicious that something was wrong with it if everybody agreed on it. But basically it provides two types of research; basic research, which companies can do in

cooperation with the University of Missouri. For every dollar the company would put up, the State of Missouri would put up a dollar. It was an incentive to get companies involved in basic research utilizing our academic facilities.

You mentioned Monsanto, which in our State has been a leader in this long range research application, particularly in the field of agriculture. In our other State colleges and universities they have applied research projects, and this is bringing the knowledge to bear on a marketable product. For each \$2 that the private company puts up, the State of Missouri adds \$1 to encourage them to use State colleges and universities in their application.

Frankly, it has taken us a little while to get started, to get the word around. It is beginning to work, and I think it is going to be a viable proposal, but it is something that might very well dovetail with the kind of support and encouragement that your bill provides, Mr. Chairman, and it is a very exciting prospect.

In Northwest Missouri University they have done a lot of research on utilizing new types of fast growing fiber products for fuel. These are applications that may be very beneficial and help stop the soil erosion problem, which is very, very significant in northern Missouri and Iowa as well.

We have also adopted a Food for the 21st Century Program at the University of Missouri which is designed to utilize the full plant value. In walnut production we not only make bowls out of the wood, but we are now selling the crushed shells to use, instead of sandblasting, for walnut shell blasting, which in some applications does an excellent job.

These research activities have gone on in cooperation between private industry, universities, and the Government. I think, as you have indicated, this is a very exciting application for technology and better uses for agriculture which will provide our farmers the markets and the income they need in the years ahead.

I am enthusiastic. I am excited about the program that you have outlined, and I am most anxious to work with you and your staff on putting together a measure which would help accomplish this opportunity.

Senator HARKIN. Thank you very much, Senator Bond. In fact, I just said to my staff, let's find out what they are doing in Missouri, so maybe we learned some things there.

Senator GLENN. I was just sitting here doodling—I was listening to every word, you understand. But I was also doodling with figures a little bit. This is a ratio of 85 to 1, \$6 to \$510 million. I think that figures out right, does it not? Eighty-five to one that we are putting on production research, continuing it just because the Agriculture Department has always done that. We needed it in the past. I do not quarrel with that a bit.

But good heavens, let's jerk somebody up by the leash over there and say we have got to change this thing. I would like to see that ratio come steadily down, 10 to 15 percent a year until we get it down to a reasonable level; 85 to 1 and we have got such surpluses that we do not know what to do with them, and driving people off the farm because of it.

Senator HARKIN. A point well made. Senator Glenn, again, thank you very much for your testimony.

Senator GLENN. Thank you. I appreciate the opportunity.

Senator HARKIN. Next let's turn to David Kingsbury, Assistant Director for Biological, Behavioral, and Social Sciences of the National Science Foundation.

Again, your statement will be made a part of the record in its entirety. Please proceed, and then when you finish we will then go to questions from both of you gentlemen.

**STATEMENT OF DR. DAVID T. KINGSBURY, ASSISTANT DIRECTOR,
BIOLOGICAL, BEHAVIORAL AND SOCIAL SCIENCES, NATIONAL
SCIENCE FOUNDATION**

Dr. KINGSBURY. Thank you Senator. I would like to thank the committee for this opportunity to discuss the future of biotechnology and agriculture and to comment on S. 970, the Alternative Agricultural Products Research Act of 1987.¹

I believe that the answer to the dilemma of the farmer does not lie in the continued Government support for excess production, for crops not grown, but to find new directions for agricultural resources to once again make the farm a growing segment of our national economy. To achieve this goal we will all have to apply imagination and new technologies.

In his State of the Union message earlier this year the President focused on the role of basic research in enhancing international competitiveness for our industries. This is no less true in agriculture than it is in microelectronics and new materials. In modern biology we have just begun to apply the new techniques we collectively call biotechnology.

The authors of S. 970 should be applauded for their recognition of the role that well designed basic research can play in solving this problem. However, we must recognize that technology alone cannot restore a farming system that is not in tune with the current structure of the full agricultural business picture.

Agricultural biotechnology must be placed in the broadest perspective to include all possible applications of plants and animals and to take into account the developing deep vertical integration of today's agribusiness. I would like to quote from a recent comment by Roger H. Salquist, the president and chief executive officer of Calgene of Davis, CA, who I now recognize is going to be a witness later on.

To quote: "To that end our markets and the various agribiotech applications encompass both the food and industrial sectors. Most people tend to think about the edible products of agriculture. But in the U.S. today, over \$400 million worth of industrial oils from plants are used and, if numerous research projects currently underway are successful, there will be at least \$1 billion annually in new applications of oils that come from plants."

This quote is a vivid illustration of the future of agriculture if proper thought and direction are given to new research approaches. The farming sector must be ready to be responsive to the new crop demands and be flexible to focus on the production of those crops that will meet market demand. Research must focus on the

¹ See p. 63 for the prepared statement of Dr. Kingsbury.

development of the new high value crop products so that they can be grown in the regions of this country that have the land, personnel and desire to pursue this new direction.

For the past 2 years a small group of us from the National Science Foundation, the Department of Agriculture, the Department of Energy, and the Office of Science and Technology Policy have been meeting to discuss and map the future directions for an increased effort in plant biotechnology.

One result of that planning is the Plant Sciences Research Centers initiative found in the fiscal year 1988 budget request from the NSF, USDA, and DOE. This is a small but significant step in addressing the problem. The United States has focused the largest share of its biological research on human health, and we all recognize that the results have been dramatic and many needs remain.

However, we must also recognize that agriculture is of critical importance as well. In fact, agriculture is still the largest single industry in the United States. Twenty percent of our gross national product comes out of agriculture. By our calculations only about 5 percent of our biological research support is directed toward agriculture.

The irony of this situation is that the research tools and technology are currently in place and ready to go. The question is not whether such research can be done, but rather what is the appropriate Federal role in such research and where should Federal resources be targeted?

It is clear that the authors of S. 970 recognized the potential of the new biotechnologies in agriculture, the question we must now examine is whether this is the best way to achieve our shared goals. I have several concerns with S. 970 that I would like to share with you.

First, I believe that the philosophy behind the bill ignores the changing relationships in the agricultural sector. I do not believe that we should begin our targeted research projects with the farmer in mind, but rather we should begin with the end user and work backward.

I mentioned earlier the growing vertical integration within this sector. Historically, agricultural processors have purchased products on the open commodity markets, however, today we see quite a different picture. The major processors have their own plant breeding programs.

For example, tomato processors are not just buying tomatoes on the market but are creating their own varieties with the properties that are required to enhance their end use. This is a pattern across the industry. The major processors are engineering products and integrating backwards. We must take this into full consideration if a program of developmental research is to be undertaken and to be commercially successful.

My second concern involves the details of the proposed grant program. It is my personal opinion that the language of the bill places excessive constraints on the Assistant Secretary in the administration of the program. For example, the express direction to initiate 5-year funding as a minimum condition is not in line with the type of flexibility that is needed in research, especially developmental research.

Long-term stable funding in such a developmental program, where constant surveillance and review are necessary to ensure the most rapid commercialization may be counterproductive. Likewise, I fear that the role of the New Products Research Board would inappropriately limit the flexibility of the Assistant Secretary in the development of such programs.

Finally, I must point out that S. 970 would duplicate existing authorities for conducting agricultural research that do not suffer from the restrictions and inflexibilities contained in this bill. For these reasons the administration opposes S. 970.

Mr. Chairman, thank you for this opportunity to address the committee and I am prepared to answer any questions that you or other members of the committee may have.

Senator HARKIN. Thank you very much, Dr. Kingsbury, for your thoughtful work and comments, especially your work concerning the relationship between biotechnology and the environmental issues.

I have just a few questions for Dr. Kingsbury. You used the example of the vertical integration and you talked about looking at the end users. You mentioned that the major processors have their own breeding programs, and you mentioned the tomato processors.

Again, these are food uses. These are food end uses, and it involves short-term types of new varieties, that have a longer shelf life, or plumper, or redder or things like that, but they are food end uses, and that is not what we are looking at here.

Dr. KINGSBURY. I understand that.

Senator HARKIN. We are looking for something else other than that.

Dr. KINGSBURY. I do not want to represent the commercial sector, and I think that you have a panel of people that can address this much more expertly than I can, but I believe that we see the same situation in the industrial oils area, for example. There are companies that are going to be oil marketers, that have a ready use for plant vegetable varieties that are optimising the conditions of oil production and the form that those oils take so that they are more readily applicable to industrial applications.

Through the support of the end user, again, in that context, they are working with the agribiotech companies to develop the varieties of plants, such as rapeseed and others that will produce those particular oil types, and so I think that it is not just isolated to the food sector, but I believe also in the nonfood sector we are seeing a similar kind of activity.

Senator HARKIN. You made a statement here. I would like to have you, perhaps if you could in written form, submit to the committee what you feel are the excessive constraints on the Assistant Secretary in the administration of the program as developed in the language of the bill.

Obviously, we do not want to place constraints. In fact, we want to give authority and perhaps direction and guidance, but certainly not constraints.

Dr. KINGSBURY. Yes, sir.

[The following information, requested by Senator Harkin of Dr. David T. Kingsbury, NSF, was subsequently received by the committee:]

CONSTRAINTS ON THE ASSISTANT SECRETARY OF AGRICULTURE FOR SCIENCE AND
EDUCATION IMPOSED BY S. 970

The principal administrative problems imposed on the Assistant Secretary are these:

(1) The specified grant period should be dropped and language inserted to encourage long-term support where it will be stimulatory but encouraging shorter term and directed support for those developmental projects which will be ready to turn over to the private sector in a short period. The new structure of agriculture must be recognized and the new private sector participants given the opportunity to develop products rather than having them developed only within the traditional agriculture sector;

(2) The Assistant Secretary has a large number of Advisory Committees at the current time, including a strong committee for the Competitive Grants program. While I fully agree with the idea of the special committee to deal with this new area of research, the Assistant Secretary should be "encouraged" to form a suitable committee or use one of the existing committees but not be constrained to the use of a group of government advisers who may not be fully aware of the full scope of the opportunities in all of the research sectors; and,

(3) S. 970 has ignored the costs to the Department of administration of this program and that topic should be addressed in some form. It takes people, travel, computer time etc. to administer a program this large. I would prefer to see greater specificity in designating the administrative home for the grants program so that the nature of the grant policies (i.e. fully competitive, certain fields designated?, etc.) was clear. I strongly recommend that this be a fully non-constrained open competitive grants program.

Senator HARKIN. You also said that—let me just quote this for you—"Long term stable funding in such a developmental program, where constant surveillance and review are necessary to ensure the most rapid commercialization may be counterproductive."

Well, we just heard Senator Glenn and others talk about the need for long-term funding for long-term developmental programs where we are not looking at rapid commercialization. This seems to be just the opposite of what we are talking about.

Dr. KINGSBURY. Let me explain what I am referring to here.

Senator HARKIN. That one sentence really bothers me.

Dr. KINGSBURY. Yes. I understand your point of concern. Let me try to explain my reading of the bill and how I, as someone who was not involved in its drafting and as an outsider, viewed what the point of the bill was.

It appeared to me that what you were trying to do was really two things, but principally embark on a developmental research program that would begin to redirect the focus of the agricultural sector out of being purely food producers and into nonfood programs.

But this was a developmental program. We are really not talking about basic research here. As far as I am concerned this program is far more applied than purely basic, because if we were looking at purely basic research, we now need to look at a much broader base.

For example, the National Science Foundation invests in excess of \$50 million. The last count that I made, our estimate for fiscal year 1987, is something on the order of \$65 million of basic research related to the plant sciences.

But we would not argue that that was a significant overlap with the point of this bill, because that is very fundamental research in plant sciences.

My view was that this was a developmental program. My fear is that in a developmental program you must be more conscious of the incremental increases toward development, that if one just

simply says here are 5 years and an unlimited amount of funding to develop this, that people will continue to work down a road which may or may not be the very best way to go.

But by having a constant review by an expert group one now—and again, hopefully with outside involvement of the people who are really going to be the end users—that you now will go through a developmental program. I think that if one looks in the industrial sector at their developmental programs one will find that the review cycles are very short, because one is now targeting toward an applied base rather than fundamental research where we want stability and long term approaches.

Senator HARKIN. We do provide in the bill for annual reports and it was the intent to provide for annual review. If needed, then we can modify it on that kind of a basis. But underlying that was the intent to ensure that there would be long term funding so that they would not have to come back every year and justify something, but we would have this annual report so that we could take a look at it.

That is in the bill itself.

Dr. KINGSBURY. Yes. I understand, but I was trying to make the point in my comment that one has now established that the initial grant period must be 5 years and no less, yet there are many of these programs that one can see a much shorter than 5-year turn-around time for some of the developmental programs. It seemed to me that this is a case where we are putting constraints on the Secretary for the kind of investments that they would make.

If he sees a program that is clearly going to be achieved in 3 years I think he would like to make a 3-year award, rather than being obliged to make a 5-year award even if it was only going to take 3 years to do it. That was the concern I have. That is the context in which this could—

Senator HARKIN. So it was the 5-year thing that bothered you?

Dr. KINGSBURY. It is the 5-year thing that I am really referring to.

Senator HARKIN. Well, we could look at that.

Dr. KINGSBURY. I am all in favor of a stable research base. As a scientist there is nothing more useful and assuring than recognizing the long-term stability of your funding.

Senator BOND. Mr. Chairman, if you would yield?

Senator HARKIN. Senator Bond.

Senator BOND. The period of funding, it says, shall cover the proposed research necessary for not less than 5 years or until a marketable product is developed or determined to be unattainable or unnecessary.

I wonder if that is not precisely what you are shooting at—

Dr. KINGSBURY. Yes.

Senator BOND [continuing]. Because on any research project like this there ought to be some kind of review group.

Dr. KINGSBURY. That is right.

Senator BOND. Frankly, I would like to see that review group composed not of governmental officials who have too much work to do already, but perhaps representatives from higher education, research, and related companies to determine whether they are meeting the milestones. Even if they do not have a marketable product,

a 2- or 3-year review, if they are showing great progress, then they can go on for 5, whereas if after 2 years they have not gotten anywhere it may be time to cut it off.

Would this interpretation of this language meet your concerns?

Dr. KINGSBURY. Yes, sir, that was my concern.

Senator HARKIN. Thank you. That might help this bill.

We are going to have to cut off here because we have a vote coming up at 10 o'clock.

Do you have some questions, Senator Bond?

Senator BOND. I think that was it. I was interested in his views on the constraints.

Senator HARKIN. I am too.

Senator BOND. I think that is a very helpful contribution and I believe those are good points to take into consideration in the bill.

Senator HARKIN. I had a couple more that I wanted to cover. We will see if we can get through them here.

Do you have any arguments with Senator Glenn's figures on the 510? Because I had a question on that.

Dr. BENTLEY. Mr. Chairman, I think I would like to at least submit for the record some data on utilization. When we think in terms of the figures that we have, there is about \$42 million worth in the ARS budget that is directly aimed at food and nonfood uses and utilization, and it is about \$17 million for nonfood uses.

If we may, could we submit some documents? I know that when Senator Glenn looks at figures, you have to go through and analyze these because there are related activities that say, even in coming up with new uses you have to think of the biology, the physiology, and biochemistry of plants. It may be done in another area but it might not fall into this.

I would like to submit some documentation, not in refutation necessarily, but to help the committee to take a look at it.

Senator HARKIN. Fine.

Dr. BENTLEY. As one of my associates, Dr. Tallent, pointed out, in commodity conversion and delivery, we look at this as a \$91.8 million commitment of our funds in the Department. That is our laboratories at Peoria, Philadelphia, New Orleans, and in California. So, if we might I would like to answer on that.

I do not take exception to the fact that we have to take a new look at uses. I say that we are making a great deal of emphasis in looking at new uses for products.

I guess in defense, Mr. Chairman, I would like to say that we go through cycles in this. When I cited the history, I happened to have been around and heard some of these things said some years ago. And as we cite the history, then we went through a period of time when there was deemphasis on utilization and some of our colleagues had to work hard to maintain existing programs.

Now we are in a time of change and those make some problems for us and that is why I think your comments today encourage many people in this room who have stayed with this cause for many years.

Senator HARKIN. Well, if you could submit that.

[The information follows:]

ARS RESEARCH ON UTILIZATION
SUMMARY TABLE

DESCRIPTION	FY 1987 Estimated
New Products/Process--Nonfood	\$12,668,400
New Products/Process--Food	10,528,300
Enzyme/Microbial Conversion	
Nonfood	2,997,300
Food	790,500
Sub-Total, Enzyme/Microbial	3,787,800
Biotechnological Manipulation to	
Increase End Use Value	8,040,500
Processing/Handling to	
Increase End Use Value	6,482,400
New Crops	2,731,000
TOTAL.....	\$44,238,400
Agricultural Research Service	
Research on Commodity Conversion	
and Delivery (including above).....	102,204,000

UNITED STATES DEPARTMENT OF AGRICULTURE
Agricultural Research Service

NEW CROPS

Crop	FY 1987 Estimated
Crambe	--
Cuphea	\$693
Guar	118
Guayule	1,196
Jojoba	115
Lesquerella	207
Meadowfoam	144
Rapeseed	94
Safflower	164
TOTAL	2,731

Dr. BENTLEY. If there are questions in interpretations and so forth, please call on us. We would be glad to enter into a dialog and discussion to answer any of the questions.

Senator HARKIN. I appreciate it very much. Senator Bond, do you have any other questions?

Senator BOND. No, thank you.

Senator HARKIN. Thank you very much, Dr. Bentley and Dr. Kingsbury.

Do you have anything else?

Dr. BENTLEY. No. Just to thank you for the comments and to indicate to you that we are talking about the same topic.

Senator HARKIN. I think we are and I think we can work something out. Again, there is a lot of interest in this area. Senator Bond talked about what they did in Missouri and I know I have talked with Senator Lugar about it, and I know Senator Glenn is very interested in it, so I think we can work something out in this area.

Thank you very much.

I am going to call a panel of witnesses; Richard Godown, president of the Industrial Biotechnology Association, Washington, DC; Dr. Nicholas Frey, director of Biotechnology Research at Pioneer Hi-Bred International, Inc., Johnston, IA; Roger Salquist, chief executive officer of Calgene, Inc., Davis, CA; and Dr. Harvey Drucker, chairman of Midwest Plant Biotechnology Consortium, Argonne, IL.

Senator BOND [presiding]. Mr. Godown, would you begin your testimony, please.

STATEMENT OF RICHARD D. GODOWN, PRESIDENT, INDUSTRIAL BIOTECHNOLOGY ASSOCIATION

Mr. GODOWN. Senator Bond, I am Dick Godown and it is my pleasure to appear before you today on behalf of the Industrial Biotechnology Association, a trade association that represents 60 major biotechnology companies and in excess of 90 percent of the capital currently being applied to biotechnology and certainly employs 90 percent of the people, that is to say, our member companies do.¹

On behalf of the industry I wish to commend the committee, and most especially Senator Harkin, for recognizing the importance of biotechnology research for the advancement of agriculture and for demonstrating leadership and insight into this issue.

Biologists have already used genetic engineering to develop crops that resist disease and insects. Genetic engineering is now being used to develop the plants to tolerate cold and drought, irrigation with brackish water, herbicides and other environmental limitations.

Further into the future genetic engineering may allow us to develop novel plants to produce pharmaceuticals, specialty chemicals, feedstocks, and other valuable products. S. 970 focuses on these latter advances estimated to occur at least 15 to 20 years from now, assuming such research is adequately funded.

¹ See p. 66 for the prepared statement of Mr. Godown.

I would like now to move to some specific comments about S. 970. Some people have suggested that the answer to the present problems of the agricultural community is less expenditure on research until demand catches up with supply. Long-term surpluses are not caused by better technology rooted in research. They are a marketing problem which is intrinsic to commodity price support levels set differently from their market clearing prices.

In the long run, enhancement of public and private sector capability from scientific research and technology development will provide improved products created efficiently to sell at competitive prices. It will also, as contemplated by the proposed legislation, result in completely new products.

Our base of scientific knowledge is critical to agriculture, yet these scientific and technological resources have grown at rates much below those for biomedical research and at rates which are generally believed to be insufficient to sustain a strong U.S. agricultural industry into the 21st century. The essential element is competitive funding for basic research and generic applied research, yet plant science is currently supported at only about 5 percent—\$110 million—of the total Federal obligations for competitive grants in basic biological and medical research. That is \$2.2 billion.

Biotechnology is just as applicable to agriculture as it is to medicine in developing new and improved products. The opportunities to exploit it are considerable but will be realized too slowly, or perhaps not at all, at present levels of Federal support.

Studies and recommendations published by the Experimental Station Committee on Organization and Policy, the National Academy of Sciences, the National Science Board, and the Midwest Plant Biotechnology Consortium agree that biotechnology related to plant sciences should be raised to a high priority in Federal policy planning and research funding.

The cost of developing entirely new agricultural products is not trivial and it cannot be borne by reprogramming existing research funds. Authorization and funding of an entirely new research program is required for such a bold undertaking. The proposed legislation is therefore an appropriate approach.

Development of novel agricultural products depends on two factors; basic research to enable us to better understand plant genetics, metabolism, growth and other factors; and research that is applied to translating this basic research into new and useful products.

This costly and complex process begins with research problems in biochemistry and physiology at all levels of plant structure and function and ends with separation and purification of the desired product.

We would like to commend the sponsors for their recognition of the importance of not only applied plant genetics, but also the basic biological research that must precede it and the bioprocess engineering research that must follow it. Had the bill only addressed applied plant genetic research bottlenecks would have been likely to occur in the commercialization process.

While IBA understands that it is the sponsor's intention to limit funding eligibility to research that may make it possible to modify existing plants to provide and economically separable quantity of

new products, we wish to point out that research cannot always be clearly directed towards this end.

We urge the committee in its report to make it clear that the research administrators of the proposed program should be extremely flexible in applying the legislative criteria to project selection.

I would like to end by making three quick points. IBA recommends modification of the provision favoring consortia over individual research entities. While consortia are often the most appropriate forum for massive research projects, there are many smaller projects that could be conducted by a single entity such as a university or a private research laboratory. Particularly for small biotechnology companies, the preference for research projects performed by consortia may operate as a disincentive for companies to propose individual research projects of high merit.

It is interesting to note that well over 50 percent—we are into 60 or 70 percent—of the new discoveries in biotechnology have come from the small companies, and it is particularly good, we think, to give them an opportunity to get a bite of this apple.

My second recommendation. IBA recommends deletion of the requirement that a specified number of projects be funded within a specified period of time. We believe that this could force the Government to fund nonmeritorious projects so as to comply with this provision, thereby jeopardizing the program's credibility.

Finally, we recommend deletion of the provision requiring research projects to be funded for not less than 5 years. This could result in many valuable shorter term projects going unfunded. It could also lead to abuse by researchers who seek to turn a 3-year program into a 5-year program so as to be eligible for funding.

I conclude by saying we want to commend Senators Harkin, Leahy, Lugar, and Glenn for their vision of the future of American agriculture. I would also include Senator Bond in that. We are pleased to declare our support for S. 970 with the modifications described above, and would like to characterize the reason for our strong support with this phrase: There comes a time to get off the dime. We think this will do it.

Thank you.

Senator BOND. Thank you, Mr. Godown. As you have noted as you have gone through your testimony, for the other witnesses I would emphasize that the entire statement you have submitted will be included in the record and we appreciate your highlighting those particular areas of importance that you have included in your prepared statement.

I was interested because I had some of the same concerns that you had about consortia. Do you have any suggestions as to how you would determine when you need a consortium to work on a project? What basic tasks are there? When does it get beyond a single institution?

Mr. GODOWN. The size of the project or the undertaking is probably a good criteria, but Senator, it literally should be decided on a case-by-case basis. If it is something that can be handled by a single company then that should be given the consideration, if it can be handled by one or two rather than by building of a major

consortia because by doing so you are unnecessarily building in some bureaucracy that you may not want.

Senator BOND. And you design a camel instead of a horse.

Mr. GODOWN. We used that phrase at breakfast.

Senator BOND. All right. You talked about the relatively small amount of dollars going into basic research. One of the problems that we have in the Federal Government as we are looking at the budget right now is there just does not seem to be any free money left. While we recognize the need for putting more money into basic research, are there other areas of scientific endeavor where you think the Federal Government is spending too much? Because, frankly, we are going to have to take it out of one pocket before we can put it into the other.

Mr. GODOWN. I would be loathe to attempt to point where too much money is being spent in a given area. I would simply say that we would have some strong disagreement with the prior witness who seemed to be taking the attitude that not only is the authority there, but the dollars are probably able to be devoted with a little work.

If it can be done and we are all agreed that it needs to be done, then the question is why is it not being done? That is why this bill is so important, it would cause it to be done.

Senator BOND. Well, as I look at the distinguished list of organizations that comprise the Industrial Biotechnology Association, it strikes me that they are devoting a significant amount of money to this research.

Do you have any assessment as to what the private investment in this area would be? Or perhaps what the figures would be for the members of your organization; how much money are they putting into it?

Mr. GODOWN. In order to put this thing in economic context, currently the market for biotechnology products being produced is somewhere in the neighborhood of \$5 to \$10 billion a year. We would anticipate that that market will reach \$60 billion a year by the end of the century and will go to \$100 billion in the year 2025. On a percentage basis there would be an increasingly significant amount of money which would go into basic research, but the problem is the start-up time and the getting going now.

And that is why, because our companies are small, because our industry is—it is no longer fair to call it nascent, because we have developed—but we are developing and we are developing everyday significant new advances in the health care field, of course, as well as plant and animal agriculture.

But it is significant that this bill will make available at the right time the seed money, the start-up money for the applied research to produce the products for the nonfood application of the food stuffs, and I think it is just enormously important for the country at large as well as for the industry.

Senator BOND. Have you had any experience with or any suggestions for the Higher Education Research Act approach that we are taking in Missouri? Or were you familiar with it? Have you heard about that?

Mr. GODOWN. Sir, I have not researched it. I am sorry.

Senator BOND. Well, that is probably one of the problems why it is not as successful as we would like it to be, because certainly if it has not been called to your attention they have missed a very good opportunity.

With that, let me move on and ask Dr. Nicholas Frey, director of Biotechnology Research of Pioneer Hi-Bred for his testimony.

Dr. Frey.

STATEMENT OF DR. NICHOLAS M. FREY, DIRECTOR, BIOTECHNOLOGY RESEARCH, PIONEER HI-BRED INTERNATIONAL, INC., JOHNSTON, IA

Dr. FREY. Mr. Chairman, we appreciate the opportunity to comment on this proposed legislation because we believe it represents the brightest opportunity to exploit the productive capacity of the Nation's farmers. In fact, we see this approach as the most viable long term alternative to cutting agricultural production in the United States with its attendant economic and social costs.

My name is Nicholas Frey and I am director of Biotechnology Research for Pioneer Hi-Bred International. We are primarily a genetic research company that develops and sells proprietary seed products.¹

American agriculture suffers today because the supply of food and feed greatly exceeds our ability to consume it. Domestic demand for food is not expanding significantly and consumption of grain for animal feed may actually contract in the years ahead.

Export markets upon which we have historically depended to absorb crop surpluses may never again approach the level of demand we saw in the 1970's. And given the political vagaries of the international marketplace, it would perhaps be unwise to seek a return to the previous levels of dependency on export sales.

Senate bill 970 attacks the problem of surplus domestic food and feed production by funding research which would stimulate the development of new uses, new products and thereby, new markets for agricultural produce.

Modifying or developing crops for nonfood and nonfeed uses can significantly increase demand for those crops in the long term. Emerging research applications which have the potential to create new products of industrial importance are already available. Molecular and cellular biologists can provide chemists, microbiologists, plant breeders, and engineers with the tools to undertake this important work.

The amount and duration of funding proposed in this legislation demonstrates an understanding of both the challenges and the potential rewards inherent in this effort. The problems to solve are complex. They will require teams of scientists with far-ranging skills working together. Interdisciplinary groups with expertise at the molecular level all the way through whole plant genetics will be essential to the success of the program. There can be no knowledge gaps among the members of a team if the technology is to be translated into new products.

¹ See p. 72 for the prepared statement of Dr. Frey.

On the other hand, the potential returns on this investment are immense and far reaching. In addition to the obvious economic benefits which will be derived from the development of important new products and markets, we have the opportunity to help improve and stabilize the single largest segment of our economy—agriculture. We also stand to gain a much greater understanding of one of the most important natural resources—plants. Finally, this measure will help attract more quality researchers to the plant sciences.

We applaud the foresight which provides 20-year funding for this program. Initial funding of research projects for up to 5 years will allow research teams the time to develop meaningful programs. If results are forthcoming, 3-year renewals will permit promising projects to go forward while providing continuing accountability for the research. Those of us in private agricultural research have learned that success is dependent on three fundamental elements. The first two are patience and perseverance.

The third is resources, and we are encouraged that the sponsors of this legislation have recognized the need to adequately fund this program. Senate bill 970 will fund research to succeed.

Finally, we are hopeful that the board will see fit to draw upon representatives of industry, perhaps through its expert panels, to assist in identifying potential new products and viable markets for those products. Knowledge of markets, existing or potential, will be extremely important because market size is one criterion for funding.

In summary, we feel Senate bill 970 is a good bill for U.S. agriculture and for plant biological research. The amount and duration of funding are realistic and appropriate for the nature and scope of the research required. Interdisciplinary teams that incorporate a broad range of expertise from the basic sciences to the applied sciences will be required if the program is to achieve its goals. People knowledgeable in market analysis and development should be used as expert advisers to the board and perhaps to the research teams as well.

Clearly, the goal of increasing demand for agricultural produce must be the ultimate objective for all the participants in this program. We believe this bill is properly structured to achieve this objective.

Senator BOND. You mentioned your concern about the makeup of the board, and I think there has been some question about that. The members are to be appointed by various governmental agencies or officers.

Do you have any feeling for the kind of interdisciplinary board that might best be set up? What kinds of expertise would you want to see on it?

Dr. FREY. I am not so concerned about the makeup of the board. I think the initiative is fairly broad so it probably needs a broad group that is helping to advise the Assistant Secretary in the implementation of the program.

What I am concerned about is there is a heavy emphasis on markets, markets that will increase demand for agricultural produce, and I think having people that are knowledgeable about real markets, markets that make sense, is important to have as input either

to the science projects themselves, or to the board as they are deciding priorities on funding.

I think a lot of those people are going to be coming from industry. They are aware of markets, things that may expand, things that may appear to be a market but really there are some underlying economics that are not being considered so it is not really a long term viable market if you finally address it. That is the kind of thing that I was referring to.

Senator BOND. In other words, you would agree with our prior witness who said that we ought to be focusing on the end users rather than on the production capability itself in the project?

Dr. FREY. Yes. We have comments within our company, what could we do that would increase demand for corn by a billion bushels? Essentially double the corn that is used in industry today—the processing industry—and I think it is that scale of activity, something that could have some real impact, that you need to be trying to focus on. Using 100,000 bushels of corn for some niche market is not good enough unless you have enough of those niche markets to be important.

We need to look at some of those broader opportunities. If you really are going to have impact, you need a sense of an area or a sector that has some growth potential in it if you can deliver a product.

Senator BOND. To what extent does your company devote any resources to basic research, maybe in the structure of corn itself? How much effort do you put into that?

Dr. FREY. We have a very large research effort. Corn breeding, turning out varieties is something like a \$12 million investment a year, but that is backed up by research support in plant pathology, plant physiology, entomology for several million dollars, and our biotechnology research is several million more dollars.

Now, that research is to be applied, it has an applied focus to it, but we have to develop some technology internally before we even know how that can be applied to a new product. We invest very few dollars in truly basic research however.

If we saw a product opportunity that would increase the demand for corn, or any other product we sell, in the near term, we would pursue it. Unfortunately, I think opportunities that would use a billion bushels of corn are fairly long term and it is unlikely we will ever do that ourselves.

Senator BOND. That is a lot of bourbon or a lot of sweetener if you are going to use that much.

Dr. FREY. Yes, that is right.

Senator BOND. Is there some way you can explain to us as laymen what type of research you are looking at, what kinds of things you are looking into to develop these new products?

Dr. FREY. Well, right now, to be quite honest, we are going to do those things that contribute to the production of feed grains because that is the market that we sell to and we have to serve that market to remain competitive. It is only if we are competitive in that market will we be able to fund additional research that might go into some of these new use areas.

So our focus is the shorter term, the near term, what we will sell in the next 10 years.

Senator BOND. Thank you very much, Dr. Frey.

Senator HARKIN [presiding]. Mr. Godown and Dr. Frey have both given statements and now we are ready for Roger Salquist from Calgene, Inc.

Good to see you and welcome to the committee. As we have said of all witnesses, your statement will be made a part of the record in its entirety and again, please proceed as you desire.

**STATEMENT OF ROGER H. SALQUIST, CHIEF EXECUTIVE
OFFICER, CALGENE, INC., DAVIS, CA**

Mr. SALQUIST. Thank you very much, Mr. Chairman. I am especially pleased to have the opportunity to testify here today.¹

As noted, I am the chief executive officer of Calgene, Inc. We are what is called an agribusiness biotechnology company. We, I believe, have pioneered the application and the development of recombinant DNA technology in crop agricultural plants.

Among others we have major project development collaborations at the present time with the Campbell Soup Company, Philip Morris, Procter & Gamble Co., Nippon Steel, and I might note vis-a-vis your earlier comments to Dr. Kingsbury, the last two specifically focused on major new industrial applications of crop plants in the United States. We, in fact, are what is known as a start-up company. However, we will spend approximately \$7.5 million of our own funds totally focused on plant biotechnology research in the current year.

The current status of U.S. crop agriculture, I believe, is untenable. The United States cannot afford, nor should it accept a \$26 billion annual Federal agricultural subsidy cost, while simultaneously spending \$1.9 billion annually on traditional agricultural research in support of more of the same, and I would simply point out that the \$510 million figure that Senator Glenn mentioned earlier in the day is indeed only part of the \$1.9 billion figure, which by my calculations represents the total Federal and State research expenditures on agriculture in 1985.

The answer to the problem, I believe, is recognition of and adoption of the dramatic advances that have been made in biotechnology in general and plant biotechnology in particular. This situation was recognized by our National Research Council's Board on Agriculture, when in 1984, it formed a Committee on National Strategy for Biotechnology in Agriculture.

I would like to point out that report has been completed and it will be formally released in Washington, DC, on May 27. The report is entitled "Agricultural Biotechnology: Strategies for National Competitiveness."

I would like to quote from a section of that report:

Agriculture has moved from a resource-based to a science-based industry as science and technology has been substituted for land and labor. The future leadership and competitiveness of the U.S. agricultural enterprises depend upon the health and effectiveness of the agricultural research system in our country and its ability to translate better technology into practice. Research must make American farming a more profitable, reliable and durable business able to compete in both the domestic

¹ See p. 75 for the prepared statement of Mr. Salquist.

and international markets. Innovation is crucial to enhance productive efficiency and environmental acceptability. Biotechnology is the key to this innovation.

BIOTECHNOLOGY

I would like to comment briefly on the status of biotechnology as to its being doable. The power and reality of plant biotechnology are no longer speculative nor prospective. Progress in plant molecular biology, cell biology and biochemistry during the last 5 years has exceeded the sciences' own most optimistic projections. The ability to genetically engineer virtually every major dicot crop, except soybean, is now routine in the leading academic and industrial laboratories in the United States. Recent announcements suggest that the ability to engineer the major monocot crops—corn, wheat, rice, and barley—will be established in the coming months. Genes that control a wide range of commercially useful traits have been identified and many of these have been cloned and expressed in whole plants. It is now recognized and accepted that even the most complex multigenic plant pathways can be modified or controlled with single gene additions or deletions.

The net results of these scientific advances is that the initial commercial products emanating from this technology are about to enter the field development pipeline. The initial three field trials with genetically engineered plants were conducted in the United States last year and there are presently eight applications for field trials for genetically engineered plants being reviewed by the USDA. The early products expected to flow out of this growing pipeline will primarily focus on traits that will lower the unit cost of production and reduce agronomic risk. These are plants that will be herbicide tolerant, stress tolerant, and insect and disease resistant. These products will clearly improve the economics of the producers who now grow them, but they will not alter the fundamental supply and demand balance. That is the larger objective that will be addressed by the second wave of biotech products which S. 970 will help bring to fruition.

I would like to just comment on several of the specifics that I believe need to happen in conjunction with the programs envisioned by S. 970, if in fact, we are going to realize the potential of S. 970.

WHAT IS NEEDED?

One, there needs to be a continuing and expanded effort in basic plant sciences research. This would include emphasis in plant biochemistry, and physiology with a focus on gene structure, function, and regulation. This remains primarily a public sector responsibility, both as to funding and accomplishment.

Second, I think we must not lose sight of the fact that there must be a continued effort to preserve and indeed expand the diversity and integrity of our crop agricultural germplasm collection. This is obviously an issue that has gotten lots of attention in the last several years and I would point out that the advent of plant recombinant DNA technology is one of the best tools we have to allow us to expand and maintain that germplasm diversity.

Three, there must clearly be an increased emphasis on industry, Government, and academic collaboration. The focus of this collabo-

ration should be in the area of applied research and applications engineering/development. It is futile to develop new plant products for the farmer if there is not a simultaneous development of applications technology and the creation of industrial demand. Similar programs in the past, I think, have primarily faltered over this particular step. You have simply got to develop the demand and the ability to use these things simultaneously.

Four, we must continually reexamine the U.S. commercial laws and industrial policies to assure that they facilitate corporate cooperation and the interacting of commercially oriented partnerships between business, Government, and academia. I know that recent changes in the laws regarding collaboration between firms will be helpful in this area but we have to continue to focus on that.

CAVEATS

I would like to make a caveat and state that it is critical to recognize that all the dollars projected to be expended and the research and development progress that is anticipated in this area will be totally wasted if we do not continue our current efforts to establish a rational and flexible Federal biotechnology regulatory environment.

We have made dramatic progress these past 2 years under the leadership of Dr. David Kingsbury who spoke just before us. A workable regulatory program that both protects the public and the environment and which encourages commercialization of biotechnology is now in place. Changes and fine tuning obviously have to be made, but it, however, is in place. However, there will continue to be media-seeking challenges to the adequacy of our system by philosophical opponents and professional provocateurs. Those challenges clearly must be resisted and defeated. The foregoing notwithstanding, there is a clear need for expanded knowledge of the agricultural environment from micro to macro, from soil microbial ecology to climatology and hydrology.

I believe it would be appropriate to include research components in those areas in the scope of the overall projects formulated to develop new crops and products under the auspices of Senate bill 970.

In conclusion, I applaud and support the objectives and design of the Alternative Agricultural Products Research Act of 1987. This represents an important first step in allocating resources to convert the blessings of our agricultural surplus to a positive economic force in the future.

I thank you.

Senator HARKIN. Mr. Salquist, thank you very much. I was reading your statement. It is a very good statement. I appreciate it.

I am going to have some questions for you, but let's turn next to Harvey Drucker, chairman of Midwest Plant Biotechnology Consortium, Argonne, IL.

Mr. Drucker.

STATEMENT OF HARVEY DRUCKER, CHAIRMAN, MIDWEST PLANT BIOTECHNOLOGY CONSORTIUM, ARGONNE, IL

Mr. DRUCKER. Mr. Chairman, thank you for the opportunity to appear here. Perhaps it is agriculturally appropriate that we in

this particular group are somewhat representing a hybrid, on organization that contains both universities and industry.

I should say in my spoken comments I will be talking specifically about the Midwest Plant Biotechnology Consortium. My written comments are a general position on the consortia.¹

The Midwest Plant Biotechnology Consortium consist of 14 universities, 2 research institutes and 2 Federal laboratories representing essentially the major research institutes throughout the Midwest; 37 companies are involved ranging in size from small—such as Fermco Development, Agracetus, Griffith Laboratories USA—to large—Amoco, Dow Chemical and Eli Lilly. We have a farm bureau—Illinois Farm Bureau—also considered as a member.

The intent of the Consortium is rather simple. It is to develop new products and processes. The process by which we hope to do this also can be simply stated.

First of all, we hope to get a definition of problems by industry; what is required if new products are to be produced; get resolution of those problems through basic research by universities and research institutes; and then enter on the part of our industrial members into applied research programs and development programs that will eventually result in new products.

The strengths of the Consortium are also simple. We represent some excellent organizations in basic biotechnology. They are excellent organizations in plant sciences. We also have a situation where we can see clearly that by putting these organizations together we are more than the sum of our parts. No one institution is ascendant within the Consortium. We are all equal members.

We also have a strong agribusiness base. The companies that are within the Consortium represent a range of interests in agricultural sciences or in use of agricultural products: pharmaceuticals, fuels, commodity chemicals, fine chemicals, plant processing, these sectors of agribusiness are all part of the Consortium.

Also, we have within the Midwest a very strong agricultural base. As has been pointed out by many others—I will not go through it again—agricultural base that makes a lot more than anybody can eat or wear.

Others now have essentially the same sort of thing going—by others, I mean other nations—and they are beginning to look at the same sort of solution to problems; that is, to take basic applied research and begin to develop new products from agricultural surpluses. You have Project Eureka in Europe, which is a trans-European project. You have individual biotechnology projects in France, Italy, throughout Europe, indeed in Japan and throughout Asia.

What we think we like about S. 970 is it consists of more than individual projects; it allows those people with research needs and people with the research capability to satisfy those needs to meet together on common ground, and indeed, to forge a research and development enterprise that is more than the sum of its parts.

One of the things I will do later is to illustrate the way the Consortium is organized, we believe, permits small companies to benefit as much as large companies in terms of their ability to get spe-

¹ See p. 82 for the prepared statement of Mr. Drucker.

cific research done that they see as suitable for their particular enterprise.

Right now I would just like to give perhaps a small aside. Some 3 years ago Argonne Laboratory, along with two other laboratories, developed an initiative that would involve a consortium of research laboratories in industry in steel. It took us 3 years to develop that consortium.

Some 2 months ago the Japanese decided to develop a consortium in the world of superconductors. They did it in 2 weeks. That consortium consists of the best that Japanese research institutes can offer and the best the Japanese industry can offer.

The reason why I mention it is I think that they recognize, and we are beginning to recognize, the importance of working together in concerted fashion. We see this bill as a step in that direction.

Again, thank you for the opportunity to testify.

Senator HARKIN. Thank you very much for your testimony, Mr. Drucker.

The Midwest Plant Biotechnology Consortium, how does that interface with Argonne National Laboratory?

Mr. DRUCKER. We are just one of the members.

Senator HARKIN. One of the members of the Consortium?

Mr. DRUCKER. Yes.

Senator HARKIN. I see.

I am sorry, I apologize for missing the first two statements, but I had to go over to vote and come back so I missed Mr. Godown's testimony, and also that of Mr. Frey, but I will read the testimony over.

Again, when I came in here you were answering a question that Senator Bond had posed to you and the glimpse that I got of it was something about you're interest in the short term and what happens in terms of what kind of profit you can generate in the short term. Obviously, you are a stockholding company and you have to answer to your stockholders.

What was the essence of that question?

Dr. FREY. Well, I think the essence—if I can reflect a little—he was asking more or less what are we doing in this area, and I said to be quite honest I think Pioneer has more of a long term perspective to research and product development than a lot of companies. We do not look at quarterly results with quite as much attention as some. But even with that kind of a long term perspective, we still have to focus pretty well on the products that we know our customers will need and we can deliver within the next 5 to 10 years.

Some of the kinds of opportunities that will come out of research funded through the bill are probably not going to be delivered to the market in that 5- to 10-year period. While there is varying interest in some markets by different companies, such as Calgene—and we have an interest in specialty products in the long term, because they can be good for agriculture, therefore it will be good for us—but most companies are not taking a significant percentage of their research budget today for nonfood and nonfood agricultural research.

So, I think that just reemphasizes the point that the bill is needed. Industry is not going to do everything that is required to

develop a new demand for agricultural produce in the nonfood, nonfeed areas.

Senator HARKIN. I am going to address you as a panel and you can just sort of speak up as the spirit moves you. But we heard earlier Senator Glenn's testimony about the 85 to 1 ratio in agricultural research—85 going toward production and 1 going toward new uses.

Dr. Bentley said that he feels that there is a little bit of a difference there, but someone—who was it who just said that it was \$1.9 billion total——

Mr. SALQUIST. That was my figure.

Senator HARKIN [continuing]. State and——

Mr. SALQUIST. State and Federal funding for agricultural research.

Senator HARKIN. \$1.9 billion. How much of that goes toward new uses?

Mr. SALQUIST. Well, I do not have that particular chart with me and that was not the breakout. This came from the Board on Agriculture's report. The third chapter I recommend to your staff because there are a number of breakdowns, and it tended to look at it as biotechnology research as opposed to traditional research, so I honestly do not have a good figure for that.

Senator HARKIN. Would it be safe to say that there are elements going on around the country of some of the things that we are talking about here in terms of biotech research, but it is sort of fragmented, perhaps not funded for the long term? We do not have the kind of consortium put together that you spoke about that brings together private industry, academics, and Government; would that be a fair statement or not?

Mr. SALQUIST. Well, I would say that it is not completely fair. I would say that indeed there are consortia being formed around various university efforts in several parts of the country. Down in Texas, the University of Texas is focusing efforts around both industry and academia. I think that there are sort of informal consortia being formed in many cases where a biotechnology firm and an existing commercial establishment gets together and one or more universities may be participants in the program.

There has clearly been an acknowledgment of this issue at the U.S. Department of Agriculture when they formed the new Farm and Forest Products Task Force 3 years ago and I think the only argument in that case would probably be whether that group has moved fast enough and aggressively enough and what its view as to the possible refocusing of some of the existing research under that general direction might be.

There are a lot of stirrings going on in there but you certainly would not say it has been a major tidal wave moving forward.

Dr. FREY. I just might comment. I think this bill would definitely create a focus that maybe is rather diffuse today, and it would also add a lot of momentum. One of the things that I would encourage—and I know this is a difficult time—is to create new funding for this research, not merely substitute research dollars in one area for work in this area.

I think plant research needs to move forward and a greater funding of that would be helpful. How to do that, I do not know, but if

you really take the long term perspective, maybe subsidies could be diverted to fund the research.

Senator HARKIN. Yes, Mr. Drucker.

Mr. DRUCKER. Mr. Chairman, relative to this issue of diffuse, or relative to the issue of how much do we know about what each other is doing, about a year ago we held a workshop in Chicago of the Consortium members; 30 companies, at that time 15 universities.

What we saw was very interesting. In some cases it was the first time that State university staff were meeting with their colleagues in companies within the same State. They got a chance to get together and talk about what a company was doing and its research needs versus what the university was doing and how it might fill those research needs.

Now, I think what that experience told me was that minimally there is a real need for a serious dialog between industry and academia. One of the reasons why we regard this bill favorably is it would lead to such dialog. We feel—we have no basis of proof for this—that some five or six projects, for example, conjunct between industry and university arose from that one single meeting.

I do not think things are totally disjointed, but there really is a need for people to get together and think about common problems in agriculture.

Mr. GODOWN. Senator, I would simply comment that so far no witness has appeared before you—and I would be astounded if any witness appeared before you—to say that the work that needs to be done is already being done. Nor, I think, is anybody going to come before you and tell you that the money is already appropriated, the money is already available and it is simply a question of a redirection.

We think that your bill is important because it supplies a focus, because it supplies an impetus, and as I said when you were out of the room, the reason that we so strongly support this bill is because it signifies there comes a time to get off the dime, and we think that this is that time.

What you have set forth as the net result that hopes to be achieved under this bill is very definitely desirable. It needs to go forward. We hope the impetus from this hearing just builds and that it results in a measure being passed by both Houses and signed by the President.

Senator HARKIN. The impetus is there. Something is going to move. Obviously, this is a first draft. We got the best information we could to get something down on paper and to get the thing moving, and the reason we wanted you all here, and others, is to try to see if there are different suggestions you might have incorporated in the bill.

Obviously, that is the process, but I think the support is here. The support is in the Senate, not only on this committee, but as you can see, outside the committee. So, I think there is support for moving in that direction and I think we will have something this year.

Mr. SALQUIST. I was only going to comment with respect to the allocations of funding. One of my personal beliefs—it is not particularly popular in many quarters—is that what you really need to do

is look at the total of subsidy and support payments and research in on lump sum and that if you view that as the pot that you are going to allocate towards solving the problem, that that is the appropriate size pot that one should be looking to allocate, and that is not just looking at what research dollars are we spending somewhere else, it is what are we supporting to sustain the present situation or status quo.

Senator HARKIN. Exactly. Very good point. I appreciate that. Thank you.

Let me just ask a general question of all of you. If you could, describe the type of basic and applied knowledge most needed by your industries to move us toward the expansion of additional uses of plants and plant materials? This is sort of a general question if you have any thoughts.

I ask that question because my vision has been somewhat focused toward what one of you mentioned in terms of oils, cellulose, things like that. Are there others that perhaps I am not thinking about?

Mr. SALQUIST. Well, I think what you are suggesting there really, in the broadest sense in my mind, relates to plant physiology and biochemistry. In other words, in many regards you have to understand the basic functioning of plants so that you can understand how to modify them to do things more efficiently.

For instance, very little is known about how plants make starch or how they actually synthesize fibers. A lot is known about how you break them down, but what you really want to do is develop a new substrate as an input to the industrial process and the level of our knowledge in this area is pathetic compared to what we know about human physiology and human metabolism as a result of the funding for cancer research and so on that has gone on.

So in fact, one of the reasons why the oils area has moved forward, I would say, in people's thinking if not actually in practice is that there has been some very excellent work done on oil metabolism in plants—understanding how plants make oils—and until you know how they work you cannot modify them. That should be an expanded major thrust in basic research.

Mr. DRUCKER. Mr. Chairman, at our workshop we dealt with about five different agribusiness areas. Within those areas industry, as I said, essentially defined the problems and universities defined the research to fit those problems. The workshop proceedings were public, at least it was provided to all of the workshop members. We would be glad to provide that document for your record.

Essentially, confirming what the gentleman on my left has said, we would also see that there is a large set of basic research problems to be tackled, but there is also a large set of applied research problems to be tackled.

That document essentially gives you the base at least for five different sorts of agricultural uses like seed, fuel, pharmaceuticals, what might be required.

Senator HARKIN. When I talked about this bill and talked about doing these things around the countryside, a few people said, well, that is just not feasible, you cannot do those things.

Again, as a general question, what is the feasibility of developing new or modified plants that could lead to totally new products and what are some of the principal barriers to doing this?

For example, I once saw a tractor run on soybean oil. It was not very good, but it ran. So there are some useful properties there. There was one thing that we all agree, is that number one, the price of oil is going to go up and it is going to become scarcer. We all know that.

Every oil expert I ever talked to says that by the year 2000 we are going to have oil in this country between \$30 and \$50 a barrel, or more, most of them thinking closer to \$50 a barrel. Well, obviously, if we have an empty plant or facility out there that can raise crops through bioengineering that can develop a different type of an oil to replace that as a feedstock, well, we better get about it, because, obviously, it is going to take some time to get there and we are looking at 10, 12, or 15 years down the pike.

I looked at that and I just wondered, again, what is the feasibility of doing this type of thing?

Dr. FREY. Let me comment. I think it is feasible. I think it is also long term and there are some risks involved. But the point is, the price of oil is going to go up. Agriculture is going to need to increase demand, and what is the alternative? The alternative is doing nothing, and I do not really think that is one alternative that we can afford.

So I think it is very important to try something, to move forward on at least one front and look for other fronts at the same time. The barriers I see are basic knowledge of plant biochemistry, growth and development, and of processing of plant produce for new uses.

We have had discussions with a starch company who says starch for the paper industry would be better if we could lengthen the amylose chain and if we could have more phosphorous on the starch molecules. We do not know if we can modify that. We do not know if there is any diversity in corn, but that is an area that if we had a little work going we could start to find out where we could start adjusting that system to improve that product and maybe increase the demand for starch in paper.

Senator HARKIN. That is the kind of thing we are looking for. Now, from your reading of the bill, does the bill sort of move us toward that direction?

Dr. FREY. I think it should, yes.

Senator HARKIN. Well, that is what we would actually want to move toward. If we are not, then tell me how we can change it to move toward that direction, but if we are, then fine. That is the kind of input I need.

Dr. FREY. I think you are.

Senator HARKIN. Yes?

Mr. SALQUIST. I think the bill is terrific and it is doing exactly what you are suggesting to do. But just to go back a minute to your petrochemical substitution comment as to feasibility and so on.

Indeed, I believe it is clearly feasible and, in fact, if you look at today, there is a program in Malaysia on palm diesel and it is totally clear that we could engineer oil seed crops in the United States to produce a fatty-acid chain length or an oil composition that would be an effective diesel oil equivalent that not only would make the machines run but I think it would reduce the environmental pollution as the type of a feed.

So I think it is clearly there. I do not regard that research as particularly risky. I regard it as taking some time and taking some money and some dedication and I think it clearly can be done. I am reluctant sometimes as the CEO of a public company to make sort of what would be considered outlandish statements like growing porkchops on trees or things to typify the power of biotechnology, but I clearly could envision the day in the foreseeable future—meaning before the year 2000—where you could have multimillion acres of an oil seed crop in the United States producing a widely used fuel oil.

Senator HARKIN. Yes?

Mr. DRUCKER. I guess one of the things, I would agree, the basis for making products, in particular fuel, might be a good example to key on here. It really exists. But I think that we have tried to consider some take sort of a systems approach. You have to consider when you are making fuels that there is an existing infrastructure, from crude oil production to refinery. When you derive oils from crops there is an existing milling structure, there is an existing cropping structure, agriculture. How can you best use what is out there?

In the proceedings of our workshop one sees that this, in a sense, gets addressed. We state that, yes, there really is a need, for example, for advances in crop genetics; the ability, for example to clone corn, transfer genes to the corn, things of that sort.

There is also, however, a need to develop better fermentation procedures, to do the chemistry of taking corn or any other crop and to take that chemistry, couple it with the chemistry of a micro-organism, couple it to the conditions of a process reactor or a fermentation tank to make fuel.

We believe that one can take the systems level approach that would kind of optimize what is called the research benefit at every step.

Senator HARKIN. We have been joined by Senator Daschle from South Dakota, a very valuable member of this committee, who I know has a long time interest in this area of alternative uses of agricultural crops.

That is what we have been discussing here, S. 970 to try to put more focus, on alternative research. Senator Glenn was here first and he pointed out that there was an 85 to 1 ratio, he had calculated, in the Department of Agriculture—I think just on the Federal level 85 to 1 ratio; \$85 goes to research just for production purposes and only \$1 is going for new uses of those products.

He has been pushing me for some time to try to realign that a little bit. That is one of the concerns we are discussing here. I just wondered if you had an opening statement or any comments or questions for the panel?

STATEMENT OF HON. THOMAS A. DASCHLE, A U.S. SENATOR FROM SOUTH DAKOTA

Senator DASCHLE. Well, Mr. Chairman, I do not have any particular questions. I think this dialog has been very interesting. As you know, there are a lot of different activities going on today and it has taken some of our Members to those particular activities as

well. But I felt this bill in particular is one of those critical pieces of legislation wherein the solution to a lot of different problems in agriculture lie.

I have always said that you can sell the same products to more customers or more products to the same customers. You have one of those two choices, regardless; the same products to more customers or more products to the same customers.

We have focused to a large extent on selling the same products to more customers. That is what importing and exporting and the trade bill has been all about. But I think we have to focus on selling more products to the same customers, and that is what this is.

I have also felt that creating—we are all familiar with the 4-H program—there ought to be a 4-F program of food, feed, fiber, and fuel systems in this country. And in creating a 4-F program that will allow us the alternative use of agricultural products for energy, in particular, is something that is going to be here. EPA is currently toying with the idea of mandating the use of ethanol in areas where pollution has become a severe problem, congested areas in particular.

EPA-mandated ethanol could be a major boon to agriculture, but regardless of whether it is energy or the broad range of renewable products that come from the study of alternative agriculture, I think it has to be done, and your leadership in this area is not only welcome, it is an absolute necessity, and having as you have some of the experts in this area come before the committee to talk about how we can move this bill and the advantages in passing it is another major development in its progress and I just applaud you and them for carrying on this hearing this morning.

Senator HARKIN. Thank you very much, Tom. I appreciate those comments. That is right, now I remember. You are the first person I heard use that phrase, 4-F. That is pretty good, and I think that is the direction we have to start moving in.

I am hopeful that we can get this thing moving this year with the input of people like you here, any suggestions you might have.

I only have one other question, basically, for the panel, and that is, are you aware—in your capacities in your own industries or whatever—are you aware of any major plant biotechnology R&D initiatives outside of the United States? If so, could you describe any of them at all that you know of going on outside the United States?

Dr. FREY. It is a worldwide technology. Do you mean Pioneer or just in general?

Senator HARKIN. No, other countries.

Dr. FREY. There is a lot of activity. Plant biotechnology is an area that is receiving some focus in Japan and they are funding that research well. In Europe there are leading laboratories. Some of the early discoveries in the technology were coming from Europe. It is an international arena and it is not a race you can win without aggressively pursuing your goal. There will be competition worldwide, I am sure.

On the other hand, there will be opportunities worldwide if we can develop some technology here.

Senator HARKIN. Anybody else? Dr. Drucker.

Mr. DRUCKER. Well, I think, again, it is very hard to get into specifics here, but if you look at the laboratories that have been developed over the last 2 or 3 years, those that are planned, for example, there would be a laboratory dedicated to biotechnology for LDCs in Trieste, which I think is planning to open either this year or next year. That laboratory will focus, really, on plant biotechnology because that is a major area of concern. Agriculture is a major area of concern in lesser developed nations.

I think the thing is, there is no formal statement, there are no large scale, multimillion dollar single projects that I know of in either Europe or Japan in plant biotechnology, but there are a lot of small ones and I think there is the ability in those nations—I gave one example in another field—to connect those projects together relatively easily if they need to.

Senator HARKIN. Thank you all very much for taking time from your busy schedules to come here today. Your testimony was most interesting and welcome.

Again, I ask you as we move this process along, as you look at the bill, if you have suggestions, please get them to us.

Dr. FREY. Thank you very much.

Senator HARKIN. Thank you all very much.

Next, I would like to call Steve Wentworth, vice president of market development, the National Corn Growers Association and Harold Smedley, staff director for market development.

Welcome to the committee.

I first would like to say that the Corn Growers have been leaders in research to expand the use of their crop to nonfood uses. You are to be commended for that.

Let me also note that the bill clearly does provide for up to one-half of the funds authorized to be used for research aimed at the modification of existing plant materials. I am sure that any problem concerning the purpose provision can easily be taken care of in a markup.

Lastly, I would just like to say that it is my view that plant modification does not necessarily mean adopting a new plant so that it can be easily cultivated. Perhaps some more common targets of opportunities will be to take genetic material that produces a desired material and insert it into existing products like corn or soybeans. That way farmers could use existing machinery and a whole new infrastructure would not have to be developed.

So, in that regard I look forward to your testimony from the Corn Growers.

STATEMENT OF STEVE WENTWORTH, VICE PRESIDENT, MARKET DEVELOPMENT, NATIONAL CORN GROWERS ASSOCIATION, OREANA, IL, ACCOMPANIED BY HAROLD SMEDLEY, STAFF DIRECTOR FOR MARKET DEVELOPMENT, ST. LOUIS, MO

Mr. WENTWORTH. Thank you very much.

Mr. Chairman and committee members, I am pleased to have the opportunity of testifying before your committee, and to express my association's views concerning a research program targeted toward alternative agricultural products.

I am Steve Wentworth, vice president of market development of the National Corn Growers Association. I am a corn farmer from Oreana, IL and I am accompanied by Harold Smedley, our staff director for market development.

The National Corn Growers Association, NCGA, is made up of corn producers from 19 States with the purpose of enhancing and expanding the use, marketing, and efficient production of corn.

NCGA member States include Colorado, Georgia, Illinois, Indiana, Iowa, Kansas, Kentucky, Maryland, Michigan, Minnesota, Missouri, Nebraska, North Carolina, Ohio, Pennsylvania, South Dakota, Tennessee, Virginia, and Wisconsin.

As background to our interest in the legislation under consideration, I am pleased to inform this committee that our organization has launched a major initiative to identify and foster the development of alternative products utilizing corn. Our experience thus far indicates that there are significant opportunities in such diverse industries as commodity and specialty chemicals, materials development including plastics and biodegradable polymers, building materials, textiles and fibers, and energy.

In conjunction with this initiative we will convene a national corn utilization conference next month for the further examination of several of the above-noted potential areas. We are enthusiastic, for example, about the potential in viewing corn and its many fractions as chemical feedstocks. And I would add at this point that we would encourage anybody in this room to attend that conference, we have several interesting subjects.

Senator HARKIN. Where are you having that, Steve?

Mr. WENTWORTH. It will be in St. Louis, MO, June 11 and 12. If anybody is interested we have got more information and we will send you documents about that.

With additional advances in bioprocessing research and the probability of more expensive fossil feedstocks, corn products may have an expanded use in the production of commodity and specialty chemicals. This could include commercial solvents, higher alcohols, and other oxychemicals, various polymers or polymer precursors, proteins or other biochemicals, and a variety of oils.

Just as with petroleum and the many useful fractions separated in a petroleum refinery, the most efficient use of corn will include utility of all of its constituents, not just the carbohydrate content. This will include the starch, both as the polymer and as the hydrolyzed sugar, protein fraction, oils, and even the use of some corn stover and corn cobs. All of these materials have some potential utility as chemical feedstocks, and the corn refinery of the future may well have a wide and diverse product slate.

We have learned that some additional process research and development will be required to allow the effective use of corn fractions as chemical feedstocks. This will include a better understanding of bioconversion chemistry, enhanced approaches to the fractionation of corn and corn residue, the development of more efficient concepts for continuous bioreactor systems, and more effective product concentration and purification systems. Other industry sector examples can be provided.

In addition to our own efforts, the opportunities for diversified use of agricultural products, and in fact, the need for such diversifi-

cation, have been admirably documented by the recent report from the New Farm and Forest Products Task Force report to the Secretary of Agriculture.

Against that backdrop, we are pleased to have the opportunity of commenting specifically on S. 970, and begin by offering our appreciation and support for this significant initiative. It is most timely and its results hold promise of, among other things, rural economic development. We would hope, however, that specific wording of the purpose of the bill, "to authorize a research program for the modification of plants," would not exclude research on existing plant materials with demonstrated potential for new marketable industrial and commercial products. From our perspective, and with a probable corn carryover of over 5.2 billion bushels, we really do not need to search for new plant material at this time. What we need, we respectfully submit, is more effective use of existing material.

Additionally, the term "biotechnology" is significant in the language of the bill, and is not defined. It is a term that has different definitions depending on the discipline and research view. To some it means to genetically alter plants and other organisms in order to enhance the production of materials. We would encourage a more classical definition, that is, "the use of living organisms or fractions of organisms in a controlled environment to achieve a useful chemical or physical change." Perhaps a definition should be included.

In closing my remarks, I wish to highlight the fact that a more diversified utilization of our annually renewable agricultural products will produce benefits far beyond the agricultural sector with positive implications for employment and midwestern economic recovery. In light of those benefits, we see impressive wisdom in the language of the bill that involves the National Science Foundation, the Department of Energy, the Department of Commerce, and the Office of Technology Assessment. The potential benefits to the entire Nation are massive, and the work to be done of sufficient magnitude to involve broad based participation of Federal agencies and the private sector.

Once again, we support this initiative with intense motivation and interest.

We appreciate this opportunity to appear before you today, and will attempt to answer any questions that you may have about our testimony.

Thank you.

Senator HARKIN. Mr. Wentworth, thank you very much. I appreciate your being here and your fine testimony.

As I said in my opening remarks, certainly as the bill moves through we are going to make it clear that it is not just directed toward new plants but, obviously, the modification of existing plants, which you heard me just discuss with the previous panel that was here.

I was just curious as to what has been your own research investment history for the Corn Growers. Can you give us some idea about what the National Corn Growers are doing right now? Do you have much of a research budget right now? How much of this kind of research are you involved in currently? How would you respond to that?

Mr. SMEDLEY. It would be difficult for me to give you a dollar figure on it, although I could give you a percentage, and I think it is indicative of the direction in which we see the future. I would suspect that over the last 5 years we have shifted 80 to 90 percent of our research efforts away from production research toward utilization research. This is in, of course, the post-harvest phase and various forms of bioprocessing for end-product development.

Senator HARKIN. What is the potential of corn as a feedstock material for new nonfood uses? Is it broad or is it narrow?

Mr. SMEDLEY. We think it is very broad, based upon an advisory panel that we worked with through last year, a panel of product development executives of private sector companies, as well as public and private research individuals.

They identified very broad areas of potential use, the ones that were mentioned in Mr. Wentworth's testimony. Chemical feedstocks is just one. There are very broad areas, for example, in that field. In the past we have viewed ethanol simply as a motor fuel ingredient rather than a process chemical for potentially desulfurizing coal.

But in such areas as textiles and fibers, the zein protein component of corn has tremendous potential. The fiber portion has great potential in building materials. The first finished product that we will possibly see out of our efforts will be within the next couple of years from an organic chemical, a salt highway de-icer replacement.

Senator HARKIN. CMA.

Mr. SMEDLEY. Yes.

Senator HARKIN. I happen to be somewhat involved in that project.

Mr. SMEDLEY. Yes, sir, and thank you very much.

Senator HARKIN. In fact, I think we are going to be doing some work in another committee I am on this year on CMA. I know we are working together with our staffs on that.

Just on the definition of biotechnology which you mentioned, the GAO did a report on federally funded research and found that there is no common definition. That may come as a shock and surprise.

It was the intent of our drafters when we drafted this to leave it as broad as possible rather than narrowly defining it, just to give it a lot of flexibility. I know you have a definition here. Perhaps we can take a look at it and incorporate.

Again, I would just say to you the Corn Growers, thanks again for coming, and as we move this thing through, if you have suggestions or any input, please let us know.

Mr. WENTWORTH. If I can make one further comment.

Senator HARKIN. Surely.

Mr. WENTWORTH. Several of the witnesses' testimony this morning referred to the advisory panel and the overseeing of this project, and they talked about the need to have industry people there, and also the need to have academia and the researchers.

I think there needs to be a third leg to that stool. I think the producer groups, the commodity groups, need to be a part of that. The people that know how to plant the products, how to raise it and how to harvest it. I think that is crucial.

Senator HARKIN. We will take that one to heart. I think that is one leg that is missing and I think you are right, the producer groups and the commodity groups ought to be involved. I think we tend to look just toward the scientific end of it and not saying, here are the people out there that are actually going to use the result of that work.

Mr. WENTWORTH. If it cannot be grown, you need people there that can advise you about the practicality of raising and the potential levels of production.

Senator HARKIN. That might be the kind of input that we could get from USDA or something like that, perhaps. Or you were thinking more of a user group?

Mr. WENTWORTH. Yes.

Senator HARKIN. Not user group, but producer.

Mr. WENTWORTH. Commodity groups like ourselves.

Senator HARKIN. Yes. We will take a look at that.

Tom.

Senator DASCHLE. I think, Tom, that that makes a lot of sense. I do not know if there is some particular practical reason why groups could not be afforded that advisory role, but that hands-on information and knowledge is really important, for the Corn Growers in particular. You talk about a group that has really taken an active interest in alternative uses of agricultural products, I cannot think of one that has been more forceful and more able to articulate those opportunities and I think his point is well taken.

Senator HARKIN. Very good. We will take that to heart. Thank you very much.

Our last panel today will be from universities. We have Dr. B.R. Baumgardt, director of the Indiana Agricultural Experiment Station at Purdue University; Dr. Dan Zaffarano, vice president for research of Iowa State University; and David Zartman, special assistant to the vice president of agriculture at Ohio State University.

Again, welcome to the committee and I appreciate your endurance in being here for the last couple of hours. Each of your statements will be made a part of the record in their entirety. If you could please summarize them I would be most appreciative.

Let's just start as we are here with Dr. Baumgardt first.

STATEMENT OF DR. B.R. BAUMGARDT, DIRECTOR, INDIANA AGRICULTURAL EXPERIMENT STATION, ASSOCIATE DEAN OF AGRICULTURE, PURDUE UNIVERSITY, WEST LAFAYETTE, IN

Dr. BAUMGARDT. Thank you very much, Mr. Chairman. It is indeed an honor to be able to speak to this committee, particularly in reference to this bill.

Let me say up front that I do propose to simply paraphrase from my prepared statement, emphasizing some things that I think maybe would help the balance in relation to the total testimony presented so far this morning.¹

We certainly are enthusiastic supporters of the concept of this bill. In my experiences not only as the director of the Indiana Agricultural Experiment Station and the research program there, but

¹ See. p. 120 for the prepared statement of Dr. Baumgardt.

my recent opportunities to look at the total national system as the immediate past chairman of the Experiment Station Committee on Organization and Policy, or ESCOP, I think this has been helpful and I can bring some of that perspective.

Since biotechnology has been mentioned so many times, I guess I also would refer to the fact that while I am not a biotechnologist or profess to have expertise in that area, I have worked with the Land Grant Association's Biotechnology Committee since its beginning. The committee did help foster the research initiative in that area in USDA.

We think this bill addresses one aspect of the most important issue facing the Nation and certainly facing agriculture. That is, it addresses one aspect of competitiveness. Several things have been said this morning about roles of various actors in the research model, and I would simply like to summarize and underscore a bit of that by saying I think you have correctly perceived that the public has an important role in providing financial support for agricultural research, and a continuing one.

Many people say that the private sector will do applied research so why should the public sector be involved. I think you have correctly noted that, first of all, basic research is largely the responsibility of the public sector. I think we do have to be more careful. I think we have to listen more to industry and be sure that we are doing kinds of research in the basic area that I would call industry oriented or targeted basic research, and I think it is important that this bill allow for that.

The second thing on applied research, certainly the companies, as has been clearly pointed out, will do the kinds of applied research for which they can capture a return on their investment in that sort of research. But this does leave a whole range of kinds of research that are applied in orientation, that sometimes relate to production, efficiency of production, and to agro-ecosystems to make sure it is applicable to specific areas of Iowa, or Indiana, or other States that are involved.

I guess the comments about production and production research are coming across almost as negative in the testimony today, Mr. Senator. I would like to just add one comment there and then move on to the specifics of the bill. I think it is very important that we stop and think about the meaning of production and research in that area and separate out things about the unit cost of production from comments or understanding of how many units should be produced.

The first of those two, the unit cost of production is largely science and technology driven. The latter, how many units should be produced, is based on a lot of things, including, largely, public policy, farm programs, et cetera.

I guess the bottom line there that I think it is essential that we all understand is that in creating the good things of this bill, the new uses, the new products, let's make sure that we have not neglected our ability to compete in a cost-effective way in producing the raw products 10 or 20 years from now that is going to supply those new products.

If we do not maintain—in fact, if we do not regain—our efficiency, our lower unit cost of production of some of these products, we

will not be able to be the suppliers of the raw material to make them. So let's not forget that. I will not dwell on it, but for that reason I have supplied to each member of this committee a copy of one of the recent ESCOP publications on the Base Program, as we call it, doing things to assure the continued competitiveness of U.S. agriculture.²

Let me turn to a few specific comments about this bill, again saying that we enthusiastically support it. I think much of the success of the bill will depend on the New Products Research Board. That has been referred to. I think it is an excellent idea. I would urge wise use of the various input panels and committees that are allowed for in that section. We think that is very important that input does include industry and other groups such as just mentioned by the corn producers, namely groups of that type.

But certainly, industry scientists, the research and development people from industry, should have advisory input here.

We think it is important that that board have some flexibility so they can adjust over time to make sure your wishes and intents are being carried out properly as new things happen and developments occur. In other words, we would urge that they not be hamstrung too much. I am not necessarily implying they are, but I am wanting to create a philosophy here of their approach.

Also, while the emphasis seems to be on the modification of plants to produce marketable products, we would urge that the full opportunities of the bill be exploited to include new uses of existing products and crops to maintain that U.S. competitiveness, again, if you will. Also, to enhance markets for existing products and to assure that the necessary basic research can be conducted under the funds authorized by this bill.

I think some people have brought out the importance of basic research, that we certainly still need that. We need a lot of that to be able to do the kinds of things that this bill visualizes bringing about.

You are to be commended also for very wisely understanding the need for a multi-stage review process, and when we get to that point we would hope that the first process in that review certainly would include expert panels who could provide the technical excellence so that the board would have before them an array, a portfolio of fully qualified, excellent proposals that have the likelihood of success, of really having some impact.

We think the criteria as described in the bill certainly are meritorious and appropriate. We would, again, urge a bit of caution that scientists be understood and that you allow for some innovation. It is awfully difficult to really predict ahead of time what a particular piece of research will or will not do.

I am reluctant to use the word serendipity, I guess, but I think a lot of very basic discovery, very strong impact discoveries have been made almost by serendipity. That is serendipity in the mind of a bright scientist, however, of being able to put together facts and take off in directions that they did not see ahead of time that

² Retained in committee files.

might really lead to something useful. So we would, again, urge that that type of flexibility be allowed.

Next to last, I would again comment on the consortia concept, and we are very supportive of that. We think that is the right way to go with this particular activity, because consortia could be put together, and in my view should be put together, to include companies of various sizes, large and small companies, large and small universities and laboratories.

That is the goal, I believe, to—as Dr. Drucker said—bring together in a synergistic way different actors who can help solve the problem. I think what you want and what we want is a solution to a very significant problem. Let's bring together and in a focused way the best talent, the best resources that we can to solve that.

One other comment about the consortia. I think it is important that industry be involved, because we work a lot with industry at Purdue University, and we find it very helpful to have industry input even in our basic research, at least advising and evaluating—we do not always take all of their advice—but so that we can keep that basic research as relevant as possible while not stifling creativity.

Secondly, then, if industry is involved at that level, they can also start to mesh up with the public sector in doing the right kinds of applied research, and then they are already poised to take it into development and quickly turn it into products, so if they can buy-in ownership early on, I think the products will move out as quickly as possible.

Finally, we would compliment you on your accurate perception of the need for long term funding, obviously, with review and the opportunity to cut off if it succeeds. But certainly that stability is important, and also that is going to require a focused attention of significant amount of funds to be successful.

We commend you on the bill and we look forward to working with you any way possible. I would be pleased to respond to any questions.

Senator HARKIN. I have a couple of questions I want to ask you, but first lets hear from the other members of the panel.

Dr. Zaffarano, it is good to see you again. Welcome to the committee.

STATEMENT OF DR. DANIEL J. ZAFFARANO, VICE PRESIDENT FOR RESEARCH, IOWA STATE UNIVERSITY, AMES, IA

Dr. ZAFFARANO. Thank you, sir. I am honored to be here.¹

The eloquence of my colleague here in describing the need for retaining some research on productivity is certainly in accord with my views on this matter. Perhaps someday farmers in Iowa and the Midwest will produce corn at the rate of 250 to 300 bushels an acre. Such efficiencies are possible if we extrapolate present technology, and these efficiencies offer a means for development of lower cost food for much of the world.

With such developments, however, there is one continuing and nagging problem: What is the best way to utilize the massive natu-

¹ See p. 126 for the prepared statement of Dr. Zaffarano.

ral factory and highly skilled labor force of people who know how to plant and how to harvest? As Senator Daschle said, to make more products for the same customers.

The answer from our perspective is simple. It comes, again, from basic economics. Competition from within the agricultural sector for the productive capacity of the natural factory is needed. We need competition for the productive space, from plants that will serve as feedstocks for new foods and for new industrial materials.

At present, we generally have only two or three major field crops in any particular region of the country. These crops, developed and grown over long periods of time, have become parts of the culture for various areas of the country and as such have taken on a dominant role in the regional economies and in regional thinking.

The result has been that most financial investment, research, and production has been directed toward these basic crops. Movement to new or modified crops, lacking an R&D base and lacking any understanding of the potential market, has been difficult. Yet, research in the United States, Canada and other nations is expanding in this area.

There is, however, a general lack of mission, purpose, and adequate funding to develop competing plants that may lead to new products and new markets for agriculture. The program proposed in this bill provides a starting point for the development of an expanded agricultural research enterprise.

We in the university community need the resources to expand our research beyond basic soil science and basic commodities. From this perspective, such a program should not be viewed as a replacement for existing programs. On the contrary, that research must continue so the production efficiencies of basic commodities can be maximized. It is beyond this research that additional funding and programs are needed so as to stimulate new plant and new product development.

The development of new or modified plants for the production of new commercial products will require a large scale, multiuniversity, multiyear funding program. There are many questions concerning the fundamental biology of plants that need to be addressed as a part of this program and such questions require the funding characteristics given in this bill.

For example, we do not yet fully understand how plants deal with a stressful environment, how they regulate growth and development, or how we can improve the natural photosynthetic process. The point here is that very basic questions must be answered as a part of any effort to develop new plants for new products.

We certainly endorse S. 970 and urge the Congress to stimulate plant sciences research so that new plants and new products can expand, diversify and stabilize our important agricultural economy.

Thank you.

Senator HARKIN. Dr. Zaffarano, thank you very much.

Now, Dr. Zartman.

STATEMENT OF DR. DAVID L. ZARTMAN, PROFESSOR, OHIO
STATE UNIVERSITY, COLUMBUS, OH

Dr. ZARTMAN. Thank you, Senator Harkin. I want to thank you and your committee for the opportunity to appear here today and carry forth the great enthusiasm and the passion that was brought to us this morning by Senator Glenn as he spoke to the benefit of this bill. We do support it very wholeheartedly from Ohio State as a university and as a State itself.¹

In the beginning, as we think about the implications of this bill, I feel it is of vital concern to talk about the purpose of the bill, where we have been speaking principally about the objectives. The purpose is to benefit the public of the United States of America. An objective may be to better the life of farmers or farming in America.

I say it is for the public that we are really speaking to the purpose, because, in fact, we are looking to the production of new products, new systems, new pharmaceutical agents, things that would either reduce pollution or conserve natural resources or improve our economic stature as a public.

Therefore, let us not be mistaken to say that we are only speaking to the cause of farmers here. We are really talking about ourselves as a broad entity.

As was very nicely stated by Dr. Baumgardt a few moments ago, publicly funded research must accomplish three things in order to deal with the criticism that when we look to an applied objective such as this, why does not industry pay the cost?

There are three categories of research that the public ought to do. One is to, in fact, pay for research that is either so expensive because of lack of basic information or time constraints, that industry cannot afford it.

Second, there is that category of research that has to do with things needed by a broad spectrum of our public but the need has so little profit potential that industry, again, cannot afford to develop it.

The third category is for those things that are of great significance and need but only a few items are needed, and again, industry cannot afford to undertake the development of such high use but limited number of elements for production.

This bill then, if I am to make three points very clear today, satisfies three very important factors. One, it is a badly needed bill. Number two, it is well-founded and its objectives are clear. The criteria are distinct and workable.

Number three, the research institution in America—meaning the land grant system in agriculture coupled with our industries—can do the job. Let's see if I can convince you now of these things.

From Ohio State University I can bring you a particular example, rather than a battery of possibilities, which I think best portrays what can be done with new product research. We are exploring a novel anaerobic fermentation process. One of the important outputs of a fermentation process is acetic acid, another is ethanol, both closely related and transformable.

¹ See p. 128 for the prepared statement of Dr. Zartman.

Current fermentation processes capture about 50 percent of the starch that is put into the process, but with this new novel anaerobic approach it appears that we are able to capture 90 percent or so of the starch that is put into the process. That is a tremendous improvement in efficiency of that system.

It then enables us to look at a process that today is not cost effective but in the future could be with proper scaling up and testing of industrial uses. Why acetic acid? Does that make a good story? I have heard you ask a few times today for particular examples of the benefit of new product research, and I think this one is a classic.

Acetic acid is used in many common industrial chemicals. Where the word acetate appears in a product it is usually a derivation of acetic acid. Presently 2.8 billion pounds of acetic acid are used in America per year. That requires about \$1 billion of investment. If this were made from cornstarch, it would utilize about 3.1 billion pounds of cornstarch. Today it is not generally made from cornstarch but rather it is synthesized in a chemical process.

Fourteen million acres of corn could be used in this fashion. It is not used today because of the inefficiency of the fermentation process. A synthetic process works more cheaply. But with the new anaerobic fermentation process we are exploring, the contrary could be the case; 14 million acres of corn could be utilized for this particular single chemical.

Ethanol, of course, has its value and it is a fermentation end-point of the process that also gives acetic acid. It is an octane enhancer, it is an antifreeze agent in gasoline and 600 million gallons are being produced in America today. That requires 240 million bushels of corn. But by the mid-1990's we anticipate that, given the energy constraints, we will be using something like 2.2 billion gallons of ethanol a year. That will require then something over 1 billion bushels of corn by the mid-1990's.

At this point I think it would be well to focus on one of the other principal issues that has been brought forward frequently today in our dialogs. The surplus of commodities is a problem, it is said. I take the contrary point of view that, in fact, it is not a problem. A problem is when we have an inadequacy of products. When we have a deficiency of these commodities we have a problem.

What we have now is an opportunity. We have an opportunity to take what is in abundance and beyond our needs for food and sustenance and turn it into useful products that will make, in fact, the way of life in America better.

The Ohio State University, by way of bringing you a further example of our approach, has a new publication known as "Ohio 21" which is our way of reporting to our public ongoing research at our Experiment Station, and you will find in your packet a copy of that publication where there is a feature article,¹ and you will notice that topic area is highlighted by Biotechnology: "Animal Biotechnology Super Options". It could just as well say plant biotechnology, and a part of this article does engage the plant work.

¹ Retained in committee files.

To bring another focus to bear here, we have a phrase at Ohio State University that is called molecular farming. This molecular farming is being undertaken by a consortium of three universities in Ohio; Case Western Reserve, Ohio State University, and Ohio University.

Its present focus is in proteins. These proteins are being produced through animal biotechnology processes. The oviduct of the chicken and the mammary gland of the cow, both being high potency protein producers, are good models from which we can learn things about new kinds of proteins that can be just as well produced by plants.

I think, in summation, it is appropriate to consider that these plant surplus commodities can be used directly in conversion to commercial output or they can be passed through an animal, as an intermediate mechanism to getting to new end-product uses.

I thank you very much for the opportunity to speak to these issues today and I hope we have a chance to explore in depth more of what this means.

Senator HARKIN. Very interesting, all three of you. I appreciate it very much. It gives me a new emphasis to move ahead aggressively on this bill.

The example of the acetic acid was interesting. The possible use of 3.1 billion pounds of cornstarch in making that. That could utilize a lot of corn.

I assume that, obviously, you would utilize it, but then there is a lot left in the corn afterward that can be used for other things too?

Dr. ZARTMAN. Precisely.

Senator HARKIN. Let me just ask all three of you, what do you see as the role of the university in this research initiative? As part of consortia? Tell me how you might see the university now?

You all kind of touched upon the idea of not necessarily just replacing what we have, but having a complement to what we have right now. Perhaps, just tell me a little bit more of how you see the role of the university, the land-grant colleges role in this endeavor?

Dr. Zaffarano.

Dr. ZAFFARANO. Senator Harkin, I see the role of the university primarily in the basic research to be done. We, for example, have been working on a number of products. One of them is a seed which we planted this last year. We planted 30 acres and we got 30 tons. It is a seed called crambe, which was really developed at Purdue University many years ago.

This material can produce an oil which is useful for industry. It is an oil which is used for making nylon. It is an oil which is used as a lubricating oil because it is a very high density long-chain molecule. We have been able to produce this. My point is, there are genes available in plants that can direct plants how to make this particular oil.

Another plant produces another oil called lauric acid, which is the thing that you get out of coconuts, coconut oil. It is used as the basis for shampoos and for Tide and so forth, for making detergents. There is a gene in another kind of plant that directs the plant to make that oil.

We know there are genes in plants available to make synthetic oil for diesel engines. We also know that there are genes identified

that will make things like interferon and so forth. I hope I live long enough to see a farm of the future in which there may be 40 acres of soybeans over there, but they do not produce the usual soybean oil, they produce a genetically different kind of oil.

We know how to grow the soybeans. The farmers know how to plant it and harvest it. Now, let's make the soybean produce lauric acid oil, primarily. We need an extraction process for that. There is another 40 acres that makes erucic acid oil, another 40 acres that makes interferon, and so forth.

The farm of the future—and I thought my colleague was going to talk about molecular farming—will be a farm in which you have implanted genes in an existing plant that we know how to grow well and direct that plant to make something different than it normally makes. This is theoretically possible to do, and this is my dream of the farm of the future. That is the kind of long-range dream that your bill here will enable us to aim toward, and that is what I mean by agricultural diversification and that is what I mean about new products.

They are within our grasp but it takes a lot of basic research to understand how the gene can be incorporated in the soybean kernel, for example, to direct that plant to direct its energies to produce something different than it normally produces. I think it is within our grasp and we can at least dream of achieving that with the kind of thrust that your bill provides.

Senator HARKIN. Thank you very much, Dr. Zaffarano.

Dr. BAUMGARDT. That is an excellent summary of the main aspect of what universities can do. I guess I see universities as the glue and the key synergistic component of this operation. Reviewing in part what I said in my oral testimony, research at the universities certainly would center on the basic properties, the basic characteristics, the information on how can we insert genes? How can we get them expressed in the right place? In the seed and not in the husk, and so on.

This needs to be done, but again I would say we need to be sure that we involved industry while we are going that basic research, keeping them aware of what is going on, taking their input and doing the basic research. And then, working with industry in applied research, some of which they would do, and some of which would be done at the universities because it still does not offer a way for the industry to capture the benefit on that.

Then I think, finally, as industry takes off to develop this, the university people can supply, if you will, consultant-type help to industry as they are trying to take these things out of the basic laboratories and put them into companies. So this is a little different way of slicing at your question, but I think it says in a functional way, in a very pragmatic way, perhaps, how universities can be very much involved in this process.

Senator HARKIN. Dr. Zartman.

Dr. ZARTMAN. Yes. I think that universities are fundamentally different from other institutions in two respects. Number one, is, that we have a tremendous breadth of talented people able to bring to bear their thoughts and their intelligence on problems of this nature. It is very difficult to think of any other situation where so many kinds of talents can be found in one unit, one entity.

Secondly, at universities, those of us who are scientists are constantly being stimulated by bright and questioning students and they bring to us the impetus to think creatively. In fact, they allow us to do that, maybe disallow us not to do it. We have to stay ahead of the students and that is quite a challenge.

Maybe a third thing in this triad of thoughts about a university as unique is that we become very responsive to our public. We have a very keen ear to our public.

Senator HARKIN. Do you think that—talking about the farm of the future where you would have the different crops or new versions of old crops producing different things—there seems to be some resistance? Someone this morning called them professional provocateurs, I guess it was. I do not know, but someone earlier this morning said that.

There seems to be some resistance to doing this kind of genetic implanting, and yet we have seen it work in the normal way—I just think of hogs. Look what we have done with hogs over several generations. We have taken that fat old hog and now we have gotten the fat off it.

To my unscientific mind that is sort of another way of doing it, it just takes a longer period of time. It is a form of breeding that just takes time, and I guess what we are talking about here is doing it with plants but shortening that time period.

Why is there so much resistance, or why do I detect that resistance out there to it?

Dr. ZAFFARANO. Partly it has to do with the pocketbook of the farmers. At the present time, I mentioned this seed, crambe, which can be grown, and it will give you almost the same income as planting soybeans—almost the same at the present time, although soybeans are depressed.

But there is no infrastructure, there is no obvious market. There is nobody out there that is ready to give you a contract to say you will produce so many tons, because we do not know how to refine the oil at the present time and there are no refineries existing that will handle this stuff.

And so people are hesitant to get into this production when they do not know whether or not the product will sell or at what price. That is part of the problem, building an infrastructure.

Senator HARKIN. Sure. Why grow it if you cannot sell it, if there is no market for it?

Dr. ZAFFARANO. I mentioned a substitute for coconut oil. That can be grown, too, and one would think that the large companies that make detergents and so forth would be interested in an alternative. I have tried to sell this to these companies to give us a guaranteed market and it is very difficult to do because they are suspicious and not ready to move yet.

Senator HARKIN. Can it be competitive in price to coconut oil?

Dr. ZAFFARANO. Not without some more breeding. We will need more breeding to do that. But it is close. It can be close.

Senator HARKIN. Interesting. I have always been told how cheap coconut oil is.

What would be some of the barriers to multiuniversity research, linking schools with others in the area of plant biotechnology and

subsequent new product development? Should we try to address any of that in this bill at all? Are there barriers there that exist?

You all represent three well-known universities that have been involved in this area for a long time. Are there barriers that exist?

Dr. ZARTMAN. The principal barrier, I would say, is in protection of proprietary rights. That is, until a product becomes patentable, it is very difficult for industry to consider taking it to market. If you have a consorting arrangement, you must establish the proprietary investment or the goodwill of each of these entities in that consortium before you begin the process.

Dr. BAUMGARDT. I think that is quite doable, also, because—it would be inappropriate to write the recipe right now—but I think there are examples in both our university and other universities where a priori arrangements were made of how the material would be protected, would be held by the sponsoring organization, by the university, but those industries involved in supporting the research in some way in the consortia would have then certain rights to licensing under certain agreements.

I think these arrangements can be worked out. I think David is exactly right, that that needs to be worked out ahead of time. I think we have come a long way on this issue.

Another barrier I think we have overcome is the idea of should something be patented or whatever that came from the public sector. In my view, absolutely it should be, because that is the way one can control and insure its commercial application.

I think we are over that hurdle, but it is important in this sort of activity here that that become a part of the process.

May I make one other comment, Senator Harkin?

Senator HARKIN. Certainly, go right ahead.

Dr. BAUMGARDT. I have heard some statements this morning about the percentage of dollars this way and that way and slashing it. I would just make the observation that—I have the calculations made in Washington here so I assume they are correct, I know they are—that the percent of the total R&D budget that is now residing in agriculture in USDA is less than 2 percent. Of our total federally supported R&D budget, less than 2 percent is through agriculture.

Senator HARKIN. That is the total R&D budget of the Federal Government?

Dr. BAUMGARDT. That is right.

Senator HARKIN. Not just agriculture?

Dr. BAUMGARDT. No. Of the total percent. So, does agriculture warrant more than 2 percent of this Nation's R&D investment? I think that that is one issue that we cannot necessarily answer now, but put on the table. I think that is a good arguing point for support of this.

Senator HARKIN. That is interesting. My staff just gave me this. Two percent of all Federal R&D goes to agriculture. Agriculture makes up 22 percent of our GNP.

Dr. BAUMGARDT. He got my next point. That is fine.

The other way of looking at it, too, is if one looks at the total USDA budget and then looks at what part of that total USDA budget is encompassed in science and education, which would include the Cooperative State Research Service, the Agricultural Re-

search Service, the National Agricultural Library and Extension Service. That also is right at 2 percent.

So only 2 percent of the total USDA budget is currently involved in science and education, and when we are talking about tradeoffs and where the dollars should come from, I neither shall attempt to be so bold as to try to answer that for you. It is a public policy issue which you will have to wrestle with. But I think that these are types of figures that the public must consider, you must consider, as we try to look at the best investment of the tax dollars for this Nation.

Senator HARKIN. I am going to end with a tough question.

Senator Glenn said that out of \$510 million for agricultural research, \$6 million was spent on new uses. Now, you are all at land-grant schools and obviously a lot of this comes down to you, how you utilize that.

If you were in charge, if you had the final say-so on how that \$510 million might be shifted a little bit, how much would you take out of that to put for new uses, if any?

Dr. BAUMGARDT. I am going to answer it, if I may, first in a local context, in pointing out first of all that there certainly are problems of the classification system. I think our Nation's agricultural research system, both ARS, which is the in-house USDA program and that in the Agricultural Experiment Stations, which is funded largely through cooperative State Research Service—both of those systems have excellent ways of categorizing and classifying our research projects. We have a wonderful data base. It has some flaws, but overall it is good.

But any data base has problems. When we try to take out the slice that has to do with new uses and new products, we do not include such things as we are doing on genetic engineering of corn to alter the amino acid composition. Now, is not that developing new crops and new products? Certainly, it is. But in the classification system it comes out as, "production," another reason why I wanted to put the caveat about overuse of the word "production".

Senator HARKIN. We have looked at that.

Dr. BAUMGARDT. So there are those kinds of inherent problems with data bases and pulling out figures.

But specifically, to answer your immediate question, in Indiana we have established two things within the last few months—well, going back 2 years to a few months. We have a new Institute for Value-added Research, cosponsored by the State of Indiana and by Purdue University. We have the Whistler Center for Carbohydrate Research being established largely with industrial money, but also with Federal money to do this very thing.

So we have already reallocated quite a few dollars. My own calculations from my station suggests that perhaps 20 percent of our dollars are actually being spent in this area, when I do count those kinds, like in the plant breeding that might by the official system show up some other way. So we already have. I think it is important to reallocate. It is important to make the hard decisions.

I think most all of us are doing that to the limit of our ability right now, but in ways to make sure we do not lose the competitiveness of being able to continue to produce that, to be the produc-

ers of that raw product, even once these new products are available.

Senator HARKIN. One thing, before I move on to the next two witnesses for an answer to the question, I want to see if we can get out to all the land-grant colleges and research stations around the country, to give us a better breakdown. Do you see what I mean?

Some of the material we are talking about, obviously, is in that area of concern, but I am sure that it is listed under production research; perhaps a better breakout of that could be developed.

Dr. BAUMGARDT. I would be pleased on behalf of ESCOP, Experiment Station Committee on Organization and Policy, to assure you that we will work with that committee that relates to the planning and structure and with the USDA to see that you get that data.

Senator HARKIN. Dr. Zaffarano.

Dr. ZAFFARANO. I am sorry. I just do not think I am qualified to make that judgment. I cannot give you the numbers at our agricultural experiment station at the present time.

What crosses my mind as you ask the question is that we are talking about \$4.4 billion for a superconducting super collider accelerator, which is more my field. I think of how a small part of that money would make such a big difference in this particular area. But to take it away from production agriculture, I would prefer not to comment because I just do not know the facts.

Senator HARKIN. I appreciate that.

Dr. Zartman, do you have any thoughts on that?

Dr. ZARTMAN. Yes. Straight away, the investment in this kind of research, new products utilization and so on, will be returned many times over in the not-so-long run, actually.

I am saying this in the vein of proprietary products that may be developed. There will be patents. There will be royalties. Those royalties will continue to sweeten the pot so that where this bill will have a finite time period and has a finite amount of money incorporated, it is really a seed from which great results will grow as the public will accept these new products and will, in fact, then enhance the whole budget process by the royalty returns.

To be direct about what could be reallocated out of our present system, I would not dare to say.

Senator HARKIN. Generally speaking, you feel that some could be redirected toward research in these areas; is that a general feeling? Through the process of developing the bill this will sort of come out as we move along, but you do all—I see the heads nodding—generally feel that some of this could be moved in that direction, without putting a dollar figure on it, or a percent figure?

Dr. BAUMGARDT. Some could, but yet if we looked at the data which is mentioned in my written testimony—I did not refer to it orally—on the demonstrated return on the investment of public funds in agricultural research over the last 20 or 30 years and the documentation, that annual rate of return is between 30 and 60 percent. That is a fantastic rate of return of tax dollars in that area, which also suggests a current underinvestment at the present time, rather than overinvestment.

Senator HARKIN. Well, you asked me a question, if I would be supportive of more funds for the total research budget, and I do not

know if I want to answer that question. I will turn the tables on you.

This panel is very good. I really appreciate you all taking time to be here and I hope that you will closely monitor the bill as it moves through the process. Any further suggestions you have for changes, modifications, things like that we will be most receptive to.

I do believe that there is a lot of support for the bill. We know that Senator Lugar is very supportive, and so is Senator Glenn. I am too, so I think it will move. Again, we just ask for your input and assistance and thank you all very much.

The hearing record will remain open for 7 days, and there will be questions submitted to witnesses for written responses which will be made a part of the record.

Thank you all again for coming. The Committee on Agriculture is adjourned.

[Whereupon, at 12:05 p.m., the committee adjourned, subject to the call of the Chair.]

APPENDIX

Statement by Orville G. Bentley, Assistant Secretary
Science and Education, United States Department of Agriculture
Before the Committee on Agriculture, Nutrition and Forestry,
United States Senate
May 15, 1987

"One way to expand the farmer's market is to develop industrial uses for farm products." These words were contained in the introduction of a chapter entitled "The Industrial Market for Farm Products" in the 1940 Yearbook of Agriculture.

"Why do we not grow a greater variety of crops, particularly to provide raw materials for industry?" This question was posed in the 1963 Yearbook of Agriculture in the chapter devoted to "The Search for New Crops."

Mr. Chairman, I welcome the opportunity to appear today before this Committee of the U.S. Senate to testify on S.970, the "Alternative Agricultural Products Research Act of 1987." I opened with the quotes from the past because I think we should recognize the fact that American agriculture has long been aware of the potential which exists for the creation of industrial and commercial products from its crops.

In 1938, Congress authorized the creation of four regional agricultural laboratories which would be devoted to product research and development. These Centers, operated by the Agricultural Research Service, and located at Peoria, Illinois; Wyndmoor, Pennsylvania; Albany, California; and New Orleans, Louisiana, have been involved in the research and development which led to many of the new products derived from agriculture, as well as for products used in the production of our food and fiber.

As an example, just a few days ago we issued a news release which stated that "Processes developed by the U.S. Department of Agriculture researchers for making a biodegradable plastic have been licensed for use by a company that hopes to have a fast degrading cornstarch-plastic resin ready for commercial manufacture within a year." This release pointed out that the resin, which is 40 to 50 percent cornstarch, could partially replace petrochemicals in polyethylene products such as trash can liners. The processes were developed by scientists at USDA's Northern Regional Research Center in Peoria.

In late 1984, then-Secretary of Agriculture John R. Block sponsored a "Secretary's Challenge Forum on New Uses for Farm and Forest Products." As an outgrowth of that forum, we proposed and Congress provided funds for a \$10 million initiative to develop new uses for a variety of crops and livestock surpluses, and to develop new products for export. I am pleased to report that this program, funded in 1987, is under way at a number of ARS locations. Raw materials under investigation include starch, vegetable oils, tallow, and cotton fiber. Use of a range of new technologies will be used to target non-food products such as detergents, paints, lubricant

oils, construction products and others. Close coordination with industry and university scientists will help assure the success of this research.

A public-private task force was also created to carefully examine the issue of finding new uses for farm and forest products, with particular emphasis being given to industrial uses. That task force, comprised of private sector, university, and federal members, has completed its work and will be issuing a final report within the next few weeks.

Mr. Chairman, I have presented this brief background to indicate that the U.S. Department of Agriculture supports research and development to find new uses for farm and forest products. As I read the purpose of S. 970 - To authorize a research program for the modification of plans and associated research, in order to develop and produce marketable products other than traditional food and fiber products - I must conclude that the department presently has sufficient authority to achieve that purpose.

My comments should not be construed as suggestive that we are against the concept of new uses research which is contained in this bill. To the contrary, as I have said, the Department is actively engaged in such research and development projects. The Administration is, however, opposed to enactment of this bill because it substantially would duplicate present authorities for research. The bill also would also authorize a \$75 million annual appropriation for each of the next 20 years. Again, I must point out that present authorities are sufficient to allow the Congress to appropriate monies for the type of research called for in this bill.

Further, the bill would establish a New Products Research Product to advise the Secretary on policies and specific research proposals for new uses. This Board would unnecessarily duplicate functions already carried out by other committees, such as the Joint Council on Food and Agricultural Sciences.

I do want to commend the sponsors of this bill and other Members of the Congress who have expressed interest and provided support to USDA's efforts to find new uses for farm and forest products. I would certainly be remiss if I did not call attention to the similar work which is being conducted by our Nation's Land-Grant Universities and Colleges, and by the Forest Products Laboratories. I am advised that later today you will be hearing from representatives of the university research community, and I am sure they will be pleased to inform the Members of this Committee of their activities.

I have with me today Dr. William Tallent of the Agricultural Research Service, and Dr. Paul O'Connell of the Cooperative State Research Service. We will be pleased to respond to any questions you might have about the ongoing activities of the Department to find new uses for farm and forest products. Thank you for giving the Department of Agriculture this opportunity to appear before the Committee.

TESTIMONY OF SENATOR JOHN GLENN

before

SENATE COMMITTEE ON AGRICULTURE

May 15, 1987

THANK YOU SENATOR HARKIN, IT IS A PLEASURE TO TESTIFY BEFORE THE SENATE AGRICULTURE COMMITTEE ON SENATE BILL 970, THE ALTERNATIVE AGRICULTURAL PRODUCTS RESEARCH ACT OF 1987. BEFORE BEGINNING MY PREPARED REMARKS, I WANT TO THANK THE COMMITTEE FOR PROVIDING THE OPPORTUNITY FOR DR. DAVID ZARTMAN, A PROFESSOR FROM OHIO STATE UNIVERSITY, TO PRESENT TESTIMONY ON THE GOOD WORK BEING DONE AT OSU ON NEW USES RESEARCH.

THE 1980S HAVE NOT BEEN KIND TO U.S. AGRICULTURE. PRICES HAVE DECLINED, FORCING INCOME LOWER. LAND VALUES HAVE DECLINED, FORCING THOUSANDS OF FARMERS OUT OF BUSINESS. UNFORTUNATELY, THIS SITUATION PROBABLY WILL NOT IMPROVE IN THE NEAR FUTURE. AS A RESULT WE MUST PROVIDE SHORT TERM AID TO ADDRESS OUR CURRENT PROBLEMS AS WELL AS DEVISE A LONG TERM STRATEGY WHICH WILL RETURN PROFIT TO AGRICULTURE.

HISTORY TELLS US THAT FARM PROSPERITY OCCURS WHEN DEMAND FOR AGRICULTURAL COMMODITIES IS IN BALANCE WITH SUPPLY. BEGINNING IN THE MID 1950S, AN EXPANDING EXPORT MARKET ABSORBED THE INCREASING SUPPLY OF COMMODITIES PRODUCED BY U.S. FARMERS. WHILE NOT EVERY YEAR WAS PROFITABLE FOR EVERY FARMER, ON BALANCE THE PERIOD BETWEEN 1955 AND 1980 WAS ONE OF ACCEPTABLE INCOME FOR THE FARM SECTOR AS A WHOLE.

SINCE 1981 FARM EXPORTS HAVE DECLINED FROM \$44 BILLION TO AN ESTIMATED \$26 BILLION IN 1986. DURING THIS SAME PERIOD DOMESTIC DEMAND FOR FOOD HAS INCREASED, BUT ONLY AT THE RELATIVELY SLOW RATE OF POPULATION GROWTH. EXTENSION OF THESE TRENDS YIELDS A SOBERING CONCLUSION -- TRADITIONAL DEMAND OUTLETS SHOW LITTLE PROMISE OF UTILIZING THE CURRENT SURPLUSES AND RESTORING PROSPERITY TO AMERICAN FARM FAMILIES.

EVEN THE POSSIBILITY THIS PREDICTION MAY BE ACCURATE SHOULD CHALLENGE US TO DEVELOP BOLD, NEW PROGRAMS WHICH LOOK TO THE FUTURE WHILE EMBRACING THE LESSON FROM HISTORY THAT FARM PROSPERITY IS LED BY DEMAND. THAT IS WHY I STRONGLY SUPPORT THE GOALS OF THIS LEGISLATION; AND AS YOU KNOW, I ALSO INTRODUCED SIMILAR LEGISLATION IN THE 99TH CONGRESS THAT WAS INCORPORATED IN THE 1985 FARM BILL. I BELIEVE NEW USES RESEARCH IS A COMMON SENSE APPROACH TO THE BIN-BUSTING SURPLUSES FACING AMERICANS IN THE 80'S.

NEW USES FOR FARM AND FOREST PRODUCTS ARE NOT FAR OFF FANTASIES THAT WILL TAKE YEARS TO DEVELOP. RIGHT NOW, CORN STARCH IS USED NOT JUST IN PRODUCING ALCOHOL BUT ALSO IN MANUFACTURING PAPER PRODUCTS, BUILDING MATERIALS, TEXTILES, AND ADHESIVES.

AND, IN MY JUDGMENT, WE HAVE JUST BEGUN TO SCRATCH THE SURFACE. MANY PETROCHEMICALS CAN BE MADE FROM CARBOHYDRATES CONTAINED IN FOOD AND FEED GRAINS. HOWEVER, MORE EFFICIENT MANUFACTURING PROCESSES NEED TO BE DEVELOPED. EVEN GREATER POTENTIAL LIES IN DEVELOPING NEW CHEMICALS AND OTHER PRODUCTS THAT UTILIZE THE DESIRABLE PROPERTIES OF STARCH AND CELLULOSE.

NEW USES RESEARCH ENCOURAGES THE APPLICATION OF BASIC RESEARCH IN BIOLOGY, CHEMISTRY, AND PHYSICS TO DEVELOP NEW USES FOR FARM AND FOREST PRODUCTS. ALTHOUGH SOME LIMITED RESEARCH IS BEING CONDUCTED BY USDA, LAND GRANT COLLEGES, AND PRIVATE INDUSTRY, THE AMOUNT SPENT IS MINIMAL. FOR EXAMPLE, IN FISCAL YEAR 1987 ONLY \$6 MILLION OUT OF A TOTAL AGRICULTURAL RESEARCH SERVICE BUDGET OF \$510 MILLION WAS SPENT ON DEVELOPING NEW USES FOR FOOD AND FEED GRAINS. EXPENDITURES ON NEW NON-FOOD USES OF FOOD PRODUCTS PALES BESIDE THE MONEY BEING SPENT ON PRODUCTION RESEARCH. THIS IMBALANCE IS ONE REASON THAT U.S. AGRICULTURE'S PRODUCTIVE CAPACITY HAS OUTSTRIPPED THE DEMAND FOR ITS PRODUCTS. SUPPLY IS BEING CREATED WITHOUT THE MARKETS TO ABSORB IT.

TO RIGHT THIS IMBALANCE, LEGISLATION REDIRECTING OUR AGRICULTURAL RESEARCH PRIORITIES IS URGENTLY NEEDED.

SENATE BILL 970 DOES NOT OFFER A SHORT TERM SOLUTION TO FARMERS. IT IS PART OF A LONG TERM STRATEGY TO RETURN PROFIT TO AGRICULTURE AND TO CREATE THE BASE FOR A THIRD GOLDEN AGE OF AGRICULTURE. SUCH A FORWARD LOOKING STRATEGY IS THE KEY TO RENEWING AMERICA'S AGRICULTURAL PROSPERITY AND RESTORING OUR FARMERS CONFIDENCE IN THE FUTURE. I LOOK FORWARD TO THAT BETTER FUTURE FOR AMERICAN AGRICULTURE AND TO WORKING WITH YOU IN SHAPING IT.

MY THANKS FOR THIS OPPORTUNITY TO TESTIFY.

Statement of Dr. David T. Kingsbury, the Assistant Director for Biological, Behavioral and Social Sciences of the National Science Foundation.

My name is David T. Kingsbury and I am the Assistant Director for Biological, Behavioral and Social Sciences of the National Science Foundation. I would like to thank the Committee for this opportunity to discuss the future of biotechnology in agriculture and to comment on S. 970 the "Alternative Agricultural Products Research Act of 1987."

There is hardly anyone among us who would deny that the United States is in the midst of a dramatic change affecting the elementary structure of American agriculture. Many farmers are moving off the farm and as a result the value of our agricultural property has dropped dramatically. There are many reasons for this situation and we have not met here to discuss the macroeconomic factors of agribusiness. However, one factor is preeminent in any analysis, the American farmer is simply out producing the market demand. This has resulted in part from dramatic increases in yield per acre of most crops and the success of our traditional trading partners in the establishment of modern efficient farming in their own countries. Indeed, many of our former customers are now our competitors in the world market place. I believe the answer to the dilemma of the farmer does not lie in continued government support for excess production or for crops not grown, but to find new directions for our agricultural resource to once again make the farm a growing segment of our national economy. To achieve this goal we will all have to apply imagination and our new technologies.

In his State of the Union message earlier this year the President focused on the role of basic research in enhancing international competitiveness for our industries. This is no less true in agriculture than it is in microelectronics and new materials. In modern biology we have just begun to apply the new techniques we call collectively "biotechnology." The authors of S.970 should be applauded for their recognition of the role that well designed basic research can play in solving this problem.

However, we must recognize that technology alone cannot restore a farming system that is not in tune with the current structure of the full agricultural business picture. Agricultural biotechnology must be placed in the broadest perspective to include all possible applications of plants and animals and to take into account the developing deep vertical integration of today's agribusiness.

I would like to quote from a recent comment by Roger H. Salquist, the president and chief executive officer of Calgene, Inc. of Davis California.

"To that end, our markets and the various agribiotech applications encompass both the food and industrial sectors. Most people tend to think about the edible products of agriculture. But in the U.S. today, over \$400

million worth of industrial oils from plants are used and, if numerous research projects currently underway are successful, there will be at least \$1 billion annually in new applications of oils that come from plants."

This quote is a vivid illustration of the future of agriculture if proper thought and direction are given to new research approaches. The farming sector must be ready to be responsive to the new crop demands and be flexible to focus on the production of those crops that will meet market demand. Research must focus on the development of the new high value crop products so that they can be grown in the regions of this country that have the land, personnel and desire to pursue this new direction.

For the past two years, a small group of us from the National Science Foundation, the Department of Agriculture, the Department of Energy and the Office of Science and Technology Policy have been meeting to discuss and map the future directions for an increased effort in plant biotechnology. One result of that planning is the Plant Sciences Research Centers initiative found in the FY 1988 budget request from the NSF, USDA and DOE. This is a small but significant step in addressing the problem. The U.S. has focused the largest share of its biological research on human health, and we all recognize that the results have been dramatic and many needs remain. However, we must also realize that agriculture is of critical importance as well. In fact, agriculture is still the largest single industry in the U.S. Twenty percent of our gross national product comes out of agriculture. By our calculations only about 5% of our biological research support is directed towards agriculture. The irony of this situation is that the research tools and technology are currently in place and ready to go. The question is not whether such research can be done, but rather what is the appropriate Federal role in such research and where should Federal resources be targeted?

It is clear that the authors of S.970 recognized the potential of the new biotechnologies in agriculture, the question we must now examine is whether this is the best way to achieve our shared goals. I have several concerns with S.970 that I would like to share with you. First, I believe that the philosophy behind the bill ignores the changing relationships in the agricultural sector. I do not believe that we should begin our targeted research projects with the farmer in mind, but rather we should begin with the end user and work backward. I mentioned earlier the growing vertical integration within this sector. Historically, agricultural processors have purchased products on the open commodity markets, however, today we see quite a different picture. The major processors have their own plant breeding programs. For example, tomato processors are not just buying tomatoes on the market but are creating their own varieties with the properties that are required to enhance their end use. This is a pattern across the industry, the major processors are engineering products and integrating backwards. We must take this into full consideration if a program of developmental research is to be undertaken and to be commercially successful.

My second concern involves the details of the proposed grant program. It is my personal opinion that the language of the bill places excessive constraints on the Assistant Secretary in the administration of the program. For example the express direction to initiate five-year funding as a minimum condition is not in line with the type of flexibility that is needed in research, especially developmental research. Long term stable funding in such a developmental program, where constant surveillance and review are necessary to insure the most rapid commercialization, may be counterproductive. Likewise, I fear that the role of the New Products Research Board would inappropriately limit the flexibility of the Assistant Secretary in the development of such programs.

Finally, I must point out that S. 970 would duplicate existing authorities for conducting agricultural research that do not suffer from the restrictions and inflexibilities contained in this bill. For these reasons, the Administration opposes S. 970.

Mr. Chairman, thank you for this opportunity to address the Committee and I am prepared to answer any questions that you or other members of the Committee may have.



**Industrial
Biotechnology
Association**

1625 K Street, N.W.
Suite 1100
Washington, D.C. 20006
(202) 857-0244
FAX: (202) 857-0237

STATEMENT OF RICHARD D. GODOWN,
PRESIDENT,
INDUSTRIAL BIOTECHNOLOGY ASSOCIATION
ON
S. 970
BEFORE THE COMMITTEE ON
AGRICULTURE, NUTRITION AND FORESTRY
OF THE
UNITED STATES SENATE
May 15, 1987

Mr. Chairman, my name is Richard D. Godown and it is my pleasure to appear before you today on behalf of the Industrial Biotechnology Association, a trade association that represents 60 major biotechnology companies. On behalf of the industry, I wish to commend the Committee, and most especially Senator Harkin, for recognizing the importance of biotechnology research for the advancement of agriculture and for demonstrating leadership and insight into this issue.

I will begin my testimony by describing how biotechnology works and the impact biotechnology is likely to have on agriculture in the future. I will then address myself specifically to the provisions of the alternative agricultural products research authorization bill, S. 970, on which this hearing focuses.

Agriculture and the New Biology

Stone Age farmers were, in a sense, the first genetic engineers. They started by planting the seeds of wild plants. Later, they selected the most productive of their domesticated plants to provide the next year's seed stock. Over thousands of years, this process gave rise to most of today's crops.

In the early 20th Century, scientists applied Gregor Mendel's classical laws of genetics to quicken the pace of crop improvements. By the 1950s, classical genetics was making enormous contributions in academic research and traditional agriculture, and it was playing a major role in the Green Revolution, which has been responsible for averting starvation in many parts of the developing world.

But classical genetic techniques, which involve sexual reproduction of plants and animals, have several limitations.

First, classical techniques are slow, requiring many years to produce a new crop variety. Many biologists believe biotechnology will enable them to develop new varieties more quickly.

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Second, only closely related species can mate. For example, primitive alfalfa and modern alfalfa have accumulated so many genetic differences that they are no longer capable of mating with each other. Thus, breeders using classical techniques often cannot transfer a desirable trait from one kind of plant to another.

But recent discoveries in biology have increased scientists' understanding of how genetic information is passed from cell to cell and from generation to generation. With this knowledge, biologists have developed a technique to transfer a gene for a desirable trait from one species to another. This technique is called recombinant DNA technology, or genetic engineering.

Biologists have already used genetic engineering to develop crops that resist disease and insects. Genetic engineering is now being used to develop plants that tolerate cold, drought, irrigation with brackish water, herbicides, and other environmental limitations. Further into the future, genetic engineering may allow us to develop novel plants to produce pharmaceuticals, specialty chemicals, feedstocks, and other valuable products. S. 970 focuses on these latter advances, estimated to occur at least 15-20 years from now, assuming such research is adequately funded.

How Genetic Engineering Works

The tools of genetic engineering are certain enzymes -- natural substances that control biochemical reactions -- that work like chemical scissors and glue, cutting and pasting DNA molecules. Biologists use these enzymes to snip genes out of DNA molecules and stick them into the DNA of plants. Or scientists can take advantage of nature's own genetic engineering ability, using microbes to insert the transplanted genes into plant cells. Genetically engineered microbes and plants express the traits coded in the new genes and pass traits on to their offspring.

Biologists move a gene from one species of plant into another with the help of a bacterium that naturally performs genetic engineering. Called Agrobacterium tumefaciens, the bacterium contains a free-floating ring of DNA, called a plasmid, that can insert some of this DNA into plant chromosomes.

The biologist removes the plasmid from Agrobacterium. A desired gene -- one that instructs the plant to produce insulin, for example -- is removed from the DNA of a donor plant, animal, or microbe and spliced into the plasmid DNA. The plasmid, carrying the gene to be transferred, is put back into Agrobacterium, which is placed in a dish with cut leaves of the recipient plant.

Where the leaves are cut, the plasmid can insert the new gene into the plant cells. The gene becomes a permanent part of the recipient plant's DNA.

Many plant cells have the remarkable ability to regenerate an entire new plant. When a whole plant is grown from a cell that contains a new gene from an *Agrobacterium* plasmid, the transplanted gene will have conferred on the plant the desired trait from the donor organism.

Genetic engineering is just one of several biotechnology methods used in plant research. Other methods include:

- o **Somaclonal variation.** Cells grown in cultures of special proteins and nutrients may display unusual genetic variations. Scientists isolate the most promising new varieties for further study. This process has already produced tastier vegetables and may soon yield low-calorie "battered" popcorn and other improved crops.
- o **Somatic embryogenesis.** In this technique, plant cells with desirable traits are grown in culture to produce genetically uniform embryos. The embryos are encapsulated as artificial seeds that contain their own fertilizer.
- o **Protoplast fusion.** With this method, scientists fuse two different plant cells and grow the resulting cell into a whole plant with the genetic traits of both parent plants. Conventional breeding techniques are then used to eliminate unwanted traits in an effort to produce a new crop that has the best qualities of both parents.

S. 970: The Alternative Agricultural Products Research Act

Science and technology have made American agriculture one of the world's most productive and competitive industries. Agriculture has been a major positive factor in the U.S. balance of trade at a time when many other sectors of our economy have lost their preeminent position. But recent global economic changes have resulted in considerable reductions in U.S. agricultural exports.

Some people have suggested that the answer to the present problems of the agricultural economy is less expenditure on research until demand catches up with supply. Long-term surpluses are not caused by better technology rooted in research; they are a marketing problem which is intrinsic to commodity price support levels set differently from their market-clearing prices. In the long run, enhancement of public and private sector capacity for scientific research and technology development will provide improved products created efficiently to sell at competitive prices. It will also, as contemplated by the proposed legislation, result in completely new products.

Our base of scientific knowledge is critical to agriculture. Yet these scientific and technological resources have grown at rates much below those for biomedical research, and at rates which are generally believed to be insufficient to sustain a strong U.S. agricultural industry in the 21st century. The essential element is competitive funding for basic research and generic applied research. Yet plant science is currently supported at only about 5% (\$110 million) of the total federal obligations for competitive grants in basic biological and medical research (\$2.2 billion).

Biotechnology is just as applicable to agriculture as it is to medicine in developing new and improved products. The opportunities to exploit it are considerable but will be realized too slowly, or perhaps not at all, at present levels of federal support.

Studies and recommendations published by the Experiment Station Committee on Organization and Policy, the National Academy of Sciences, the National Science Board, and the Midwest Plant Biotechnology Consortium agree that biotechnology related to the plant sciences should be raised to a high priority in federal policy planning and research funding.

The cost of developing entirely new agricultural products is not trivial, and it cannot be born by reprogramming existing research funds. Authorization and funding of an entirely new research program is required for such a bold undertaking. The proposed legislation is therefore an appropriate approach.

The Importance of Basic and Applied Research

Development of novel agricultural products depends on two factors: basic research to enable us to better understand plant genetics, metabolism, growth, and other factors; and research that is applied to translating this basic research into new and useful products. This costly and complex process begins with research problems in biochemistry and physiology at all levels of plant structure and function, and ends with separation and purification of the desired product. We would like to commend the sponsors for their recognition of the importance of not only applied plant genetics, but also the basic biological research that must precede it and the bioprocess engineering research that must follow it. Had the bill only addressed applied plant genetic research, bottlenecks would have been likely to occur in the commercialization process.

IBA has one major concern about the bill. Often, researchers cannot tell, during the earliest stages of research, whether a product will result from their research. Yet the bill seems to expect that researchers will be able to anticipate,

decades before a marketable product is likely to emerge, that such a product can reasonably be expected to result.

While IBA understands that it is the sponsors' intention to limit funding eligibility to research that may make it possible to modify existing plants to provide an economically separable quantity of new products, we wish to point out that research cannot always be clearly directed towards this end. We urge the Committee in its report to make it clear that the research administrators of the proposed program should be extremely flexible in applying the legislative criteria to project selection.

Other Comments

IBA is pleased that the New Products Research Board established by the bill consists not only of USDA representatives, but of NSF, DOE, and other agency personnel. While USDA possesses considerable expertise in plant biotechnology, it is not the only federal agency possessing relevant expertise. NSF, for example, has expertise in both biotechnology and bioprocess engineering.

IBA is also pleased to note that the bill permits funding of research directed toward nontraditional food and fiber products, as well as non-food, non-fiber products. Non-caloric fats and sugars may well constitute major commercial opportunities, and will enhance the public health as well.

IBA recommends modification of the provision favoring consortia over individual research entities. While consortia are often the most appropriate forum for massive research projects, there are many smaller projects that could be conducted by a single entity, such as a university or private research laboratory. Particularly for small biotechnology companies, the preference for research projects performed by consortia may operate as a disincentive for companies to propose individual research projects of high merit. And a small company may be reluctant to engage attorneys, accountants, consultants, and other professionals for the purpose of establishing a research consortium so as to competitively apply for plant biotechnology research funds that it has no guarantee of obtaining.

IBA recommends deletion of the requirement that a specified number of projects be funded within a specified period of time. IBA believes that this could force the government to fund non-meritorious projects so as to comply with this provision, thereby jeopardizing the program's credibility. IBA encourages the committee to ensure federal agency compliance through its oversight mechanism.

IBA also recommends deletion of the provision requiring research projects to be funded for not less than five years.

This could result in many valuable shorter term projects going unfunded. It could also lead to abuse by researchers who seek to turn a three year program into a five year program so as to eligible for funding.

Conclusion

IBA wishes to commend Senators Harkin, Leahy, Lugar, and Glenn for their vision for the future of American agriculture. IBA is pleased to declare its support of S. 970 with the modifications described above.

STATEMENT OF DR. NICHOLAS M. FREY, DIRECTOR OF
BIOTECHNOLOGY RESEARCH, PIONEER HI-BRED
INTERNATIONAL, INC.

Mr. Chairman, distinguished committee members -- we appreciate the opportunity to comment on this proposed legislation because we believe it represents the brightest opportunity to exploit the productive capacity of this nation's farmers. In fact, we see this approach as the most viable long-term alternative to cutting agricultural production in the U.S. with its attendant economic and social costs.

My name is Nicholas Frey and I am Director of Biotechnology Research for Pioneer Hi-Bred International, Incorporated. We are primarily a genetic research company that develops and sells proprietary crop seeds.

American agriculture suffers today because the supply of food and feed greatly exceeds our ability to consume it. Domestic demand for food is not expanding significantly and consumption of grain for animal feed may actually contract in the years ahead.

Export markets, upon which we have historically depended to absorb crop surpluses, may never again approach the level of demand we saw in the 1970s. And given the political vagaries of the international marketplace, it would perhaps be unwise to seek a return to the previous levels of dependency on export sales.

Senate Bill 970 attacks the problem of surplus domestic food and feed production by funding research which would stimulate the development of new uses, new products and thereby, new markets for agricultural produce.

Modifying or developing crops for non-food and non-feed uses can significantly increase demand for those crops in the long-term. Emerging research applications which have the potential to create new products of industrial importance are already available. Molecular and cellular biologists can provide chemists, microbiologists, plant breeders and engineers with the tools to undertake this important work.

The amount and duration of funding proposed in this legislation demonstrates an understanding of both the challenges and the potential rewards inherent in this effort. The problems to solve are complex. They will require teams of scientists with far-ranging skills working together.

Interdisciplinary groups with expertise at the molecular level all the way through whole plant genetics will be essential to the success of the program. Expertise at the whole plant or grain level must mesh with expertise in fermentation, engineering and product purification. Basic understanding of enzyme function and stability must complement practical knowledge in crop production or agronomy. There can be no knowledge gaps among the members of a team if the technology is to be translated into new plant products.

On the other hand, the potential returns on this investment are immense and far-reaching. In addition to the obvious economic benefits which will be derived from the development of important new products and markets, we

have the opportunity to help improve and stabilize the single largest segment of our economy - agriculture. We also stand to gain a much greater understanding of one of our most important natural resources - plants. And finally, this measure will help attract more quality researchers to the plant sciences. The scientists trained after World War II are retiring. We need to encourage bright, dedicated young people to take their places if this country is to maintain its preeminent place in agricultural research.

We applaud the foresight which provides 20-year funding for this program. Initial funding of research projects for up to five years will allow research teams the time to develop meaningful programs. If results are forthcoming, three-year renewals will permit promising projects to go forward while providing continuing accountability for the research. Those of us in private agricultural research have learned that success is dependent on three fundamental elements. The first two are patience and perseverance.

The third is resources, and we are encouraged that the sponsors of this legislation have recognized the need to adequately fund this program. The interdisciplinary research teams which will be required on most projects necessitate that the work of several scientists be supported if the work is to be carried out in a timely manner. That provision has not been anticipated in most agricultural research grants heretofore available. Large research projects - particularly those which seek to break new ground - require significant funding if they are to succeed. Witness the time, effort and money which have gone into research on some of the problems in the human health field. Senate Bill 970 will fund research to succeed.

With the committee's indulgence, we would like to offer one suggestion with respect to subsection 5 under Section 5, Research Programs, which deals with non-traditional food and fiber uses. We would urge that those projects which create new demand for food or fiber be given a higher priority for funding than those which merely displace another domestically-produced food or fiber product in the marketplace. We respectfully submit that such language is in keeping with the spirit and intent of the Bill and would encourage appropriate research proposals.

Finally, we see a great deal of merit in establishing an advisory board from a cross section of disciplines and with a broad perspective to help the Assistant Secretary of Agriculture administer this program. We are hopeful that the board will see fit to draw upon representatives of industry, perhaps through its expert panels, to assist in identifying potential new products and viable markets for those products. Knowledge of markets, existing or potential, will be extremely important because market size is one criterion for funding.

In summary, we feel Senate Bill 970 is a good bill for United States' agriculture and for agricultural research. The amount and duration of funding are

realistic and appropriate for the nature and scope of the research required. Interdisciplinary teams that incorporate a broad range of expertise from the basic sciences to the applied sciences will be required if the program is to achieve its goals. People knowledgeable in market analysis and development should be used as expert advisors to the Board and perhaps to the research teams as well.

Clearly, the goal of increasing demand for agricultural produce must be the ultimate objective for all the participants in this program. We believe this Bill is properly structured to achieve that objective.

THE DEVELOPMENT OF NEW COMMERCIAL OPPORTUNITIES
FOR U.S. CROP AGRICULTURE

Testimony by: Roger H. Salquist
Chief Executive Officer
Calgene, Inc.
1920 Fifth Street
Davis, CA 95616
(916) 753-6313

Before the: United States Senate Committee
on Agriculture, Nutrition
and Forestry

May 15, 1987

INTRODUCTION

During the last 60 years, U.S. crop agriculture has experienced the most dramatic technologic transformation of any industry in the world. Starting with the commercial introduction of hybrid corn seed in the 1930's and followed by the successful introduction and effective use of chemical fertilizers, mechanical farm equipment, agrichemicals, and most recently computerization, U.S. crop agricultural production has established an unsurpassed standard of quality, stability and efficiency. U.S. agriculture has historically been and remains today the number one industry in the United States.

However, the very success of U.S. agriculture now threatens it's future economic viability. The adoption of successful U.S. agricultural practices in other countries around the world the past ten years has resulted in staggering world commodity crop surpluses that are exacerbated by government subsidy programs which encourage further unneeded production and lower commodity crop prices. Few would have predicted even five years ago that India would be a net exporter of wheat or that Saudi Arabia would be an exporter of poultry.

The prospects for fundamental improvements in agricultural markets in the coming years are not bright. Despite the staggering costs of agricultural subsidies to foreign governments there is clear evidence that they will increase and not diminish as hoped. Every European government has a soybean import substitution subsidy and development program in place. We have not yet begun to see the impacts of an aggressive China in world markets for cotton, soybeans and rice. We are in daily economic combat with our Canadian and Australian allies for an increasing share of a dwindling world wheat export market.

PROGNOSIS

The current status of U.S. crop agriculture is untenable. A coherent, multi-pronged attack on the problem must be mounted. Traditional solutions focusing on conventional methods through entrenched bureaucracy will not do the job. The U.S. cannot afford nor should it accept a \$26 billion annual federal agricultural subsidy while simultaneously spending \$1.9 billion annually on traditional agricultural research in support of more of the same.

The primary answer to the problem is recognition of and adoption of the dramatic advances that have been made in biotechnology in general and plant biotechnology in particular. This situation was recognized by the National Research Council Board on Agriculture when it established its committee on the National Strategy for Biotechnology in Agriculture (NSBA) in 1984. That committee, under the chairmanship of Charles Hess, Dean of the College of Agriculture and Environmental Sciences at the University of California at Davis has just completed its report entitled "Agricultural Biotechnology: Strategies for National Competitiveness" (National Academy Press, March 18, 1987). That report will be formally released and presented by Dean Hess at a press conference in Washington DC on May 27. However, I believe it is appropriate to quote the following sections on the executive summary of that report:

"The International Dimension - Agriculture has moved from a resource-based to a science-based industry as science and technology has been substituted for land and labor. This transition, which began in the United States, now affects agricultural food processing systems throughout the world. Technology has driven this change toward more effective and efficient production practices. But, current political and economic policies governing agriculture do not fully recognize nor take these changes into account. The adoption of new technologies has improved the efficiency of agricultural production practices: the causes of current agriculture surpluses lie elsewhere. Agricultural systems throughout the world continue to adopt new and better technology that enable them to become more efficient and competitive in developing new markets and capturing old markets for their agricultural products. The future leadership and competitiveness of the U.S. agricultural enterprises depend upon the health and effectiveness of the agricultural research system in our country and its ability to translate better technology into practice. Research must make American farming a more profitable, reliable and durable business able to compete in both the domestic and international markets. Innovation is crucial to enhance productive efficiency and

environmental acceptability. Biotechnology is the key to this innovation.

"American agriculture has achieved its pre-eminence through innovation and substitution of knowledge for resources. This must continue. But technological innovations cannot revitalize American agriculture unless farm business management, farm policy, U.S.D.A., land grant universities, extension services and private sector businesses that serve agriculture are innovative.

"Leadership and technology development and utilization is the role the U.S. has, can and should play for the world. American farmers can take a leadership role in adopting new biotechnologies. These technologies emphasize maximizing economic yield rather than total production. That is, they should increase the efficiency of production by reducing cost per quantity of production. Such technologies become increasingly important as support prices are moved and world competition stiffens.

"Focusing on increasing profits by reducing costs requires augmenting our knowledge in the agricultural sciences, especially those fundamental disciplines that underline biotechnology development. For example, how can one design crops that grow more efficiently and yield more nutritional food? Research will open the door to ever better technologies and products. In both research and development our U.S.D.A. laboratories, land grant universities and other public and private institutions have a critical role to play."

The Alternative Agricultural Products Research Act of 1987 (S970) is an effective tool for focusing the power of biotechnology on the inherent productivity in U.S. crop agriculture to realize new major markets.

BIOTECHNOLOGY

The power and reality of plant biotechnology are no longer speculative nor prospective. Progress in plant molecular biology, cell biology and biochemistry during the last five years has exceeded the sciences' own most optimistic projections. The ability to genetically engineer virtually every major dicot crop (except soybean) is now routine in the leading academic and industrial laboratories in the U.S. Recent announcements suggest that the ability to engineer the major monocot crops (corn, wheat, rice, barley) will be established in the next several months. Genes that control a wide range of commercially useful traits have been identified and many of these have been cloned and expressed in whole plants. It is now recognized and accepted that even the most complex multigenic plant pathways can be modified or controlled with single gene additions or deletions.

The net results of these scientific advances is that the initial commercial products emanating from this technology are about to enter the field development pipeline. The initial three field trials with

genetically engineered plants were conducted in the U.S. last year and there are presently eight applications for field trials for genetically engineered plants being reviewed by the U.S.D.A. The early products expected to flow out of this growing pipeline will primarily focus on traits that will lower the unit of cost production and reduce agronomic risk. These are plants that will be herbicide tolerant, stress tolerant and insect and disease resistant. These products will clearly improve the economics of the producers who now grow them, but they will not alter the fundamental supply demand balance. That is the larger objective that will be addressed by the second wave of biotech products which S970 will help to bring to fruition.

The second wave of products will focus on quality alterations and enhancements and these changes will create the new markets for U.S. crop agriculture. The first products will likely come from the manipulation of plant oils. It will, for example, be possible to genetically modify oilseeds to produce oils which have greatly expanded applications in the lubricant, plastics, and nylon synthesis businesses. It will also be possible to alter starch producing plants to create new and more effective products for the pulp, paper and textiles industries. Traditional markets will be expanded by engineering superior post-harvest physiology characteristics into a wide range of fruits and vegetables destined for a less seasonal and significantly expanded fresh market.

Perhaps the greatest opportunity of all which exists for marrying the U.S. agricultural resource base and productive potential with new technologies is the development of crop sourced chemical feedstocks as substitutes for fossil fuels. The range of forecasts for prices and availability of oil and gas over the next 20 years vary widely, but they all have two things in common. Prices will be higher and supplies will be more limited. It is clear that this area represents a major potential for the development of non-traditional uses of plants.

WHAT IS NEEDED?

These positive scientific advancements and new product opportunities represent only the tip of the iceberg. A great deal needs to be accomplished to realize these opportunities:

- 1) There needs to be a continuing and expanded effort in basic plant sciences research. This would include emphasis in plant biochemistry, and physiology with a focus on gene structure, function and regulation. This remains primarily a public sector responsibility both as to funding and accomplishment.
- 2) There must be a continued effort to preserve and indeed expand the diversity and integrity of our crop agricultural germplasm collection.

- 3) There must be increased focus on industry, government, academic collaboration. The focus of this collaboration should be in the area of applied research and applications engineering/development. It is futile to develop new plant products for the farmer if there is not a simultaneous development of applications technology and the creation of industrial demand.
- 4) We need to educate an entire generation of senior finance and planning executives at the major corporations of America on the structure and potential of agribusiness in the United States. There is not one major graduate business school in the U.S. that has a program, let alone courses devoted to analysis and understanding of our largest industry. You can't play the game if you don't know the rules.
- 5) We must continually reexamine the U.S. commercial laws and industrial policies to assure that they facilitate corporate cooperation and the interacting of commercially oriented partnerships between business, government and academia.

The NSBA report recognizes the importance of the government industry interface. That reports notes in its conclusion as follows:

"Applications in Commercialization: the goal of technology transfer has always been implicit in U.S. science policy. Federally funded research should benefit the public, and such benefit includes the development and transfer of technologies from public laboratories to private industry. Translating basic research discoveries into commercial applications and social benefits requires a complex set of interactions involving many types of people and institutions. Universities as well as state and federal agencies are expanding their relationships with the private sector as they explore ways to increase scientific communication in the flow of technology.

"The rapid rate of breakthroughs in molecular biology and biotechnology and their potential commercial applications have lead to more formal and aggressive transfer of biotechnology. The shift has promoted collaborative research relationships between publicly supported scientists in universities and federal laboratories and those in the private sector. Consultancies, affiliate programs, grants, consortia research parks, and other forms of partnership between public

and private sectors foster communication in technology transfer.

"The scientific advances that made biotechnology possible came out of basic research funded mainly by our federal government and carried out primarily by universities. Research in other nations has also made valuable contributions to this area. In contrast, industry support for basic research is quite limited and cannot be expected to compensate for reduction in federal funding. Thus, continued research efforts at universities remain highly dependent on federal and state governments for support.

"Patenting, licensing and regulatory issues are all areas that affect the rate and costs of technology transfer. In agricultural biotechnology, technology transfer has been hindered by federal government delays in implementing a mechanism to regulate environmental testing of the products of biotechnology. Although patent policy has been modified at the federal level to overcome obstacles it has kept government and university sponsored research from being commercially exploited, many government and university institutions retain policies that inhibit the transfer of technology to industry. Of particular importance in technology transfer from federal laboratories will be implementation of the Federal Technology Transfer Act of 1986.

CAVEATS

It is critical to recognize that all of the dollars projected to be expended and the research and development progress that is anticipated will be totally wasted if we do not continue our current efforts to establish a rational and flexible federal biotechnology regulatory environment. We have made dramatic progress this past two years under the leadership of Dr. David Kingsbury, Assistant Director Biological, Behavioral and Social Sciences of the National Science Foundation. A workable regulatory program that both protects the public and the environment and which encourages commercialization of biotechnology is now in place. However, there will continue to be media seeking challenges to the adequacy of our system by philosophical opponents and professional provocateurs. These must be defeated. The foregoing notwithstanding there is a clear need for expanded knowledge of the agricultural environment from micro to macro - from soil microbial ecology to climatology and hydrology. It would be appropriate to include research components in those areas in the scope of overall projects formulated

to develop new agricultural crops and products under the auspices of S970.

Effective administration of the program envisioned by S970 will be critical to its success. The emphasis must be on the quality of the research and the reality of the commercial objectives. This can be best assured by a strong competitive environment for project funding. Awards should not be biased in favor of longer term projects nor against individual research entities. The need for efficient multi-disciplinary scientific linkages in integration of the product development and market development often will favor a single entity approach. The inter-agency management of this program is a key in this regard.

CONCLUSIONS

In conclusion I applaud and support the objectives and design of the Alternative Agricultural Products Research Act of 1987. This represents an important first step in allocating resources to convert the blessings of our agricultural surplus to a positive economic force in the future.

STATEMENT
FOR
SENATE COMMITTEE ON AGRICULTURE,
NUTRITION AND FORESTRY

by

Harvey Drucker, Chairman
Midwest Plant Biotechnology Consortium

BIOTECHNOLOGY: THE IMPORTANCE OF SYNERGISM

We live in interesting times. Through a bit of Mendelian genetics; dashes of creative chemistry, biochemistry, and biology; and a significant dollop of crude oil converted into the muscle of machinery, every year fewer people can produce more crops, meat, and fiber than the populations of most western (and some eastern) nations can consume. The exporting of crops, once limited, like the exporting of automobiles, to a handful of nations, has become part of the economic fabric of many nations. Thus American crop exports are falling and American crop subsidies are rising. We do have company in our misfortune; the same situation exists for most nations that produce agricultural product in excess.

The solutions to this dilemma appear simple. The number of farmers can be cut, more land can be left fallow, new uses can be found for crops, or new crops can be found for new uses. All of these solutions are currently being applied all over the planet. What can the American agricultural enterprise--farmers, agribusiness, and the agricultural and plant research establishment--do that would be novel and effective; effective in the sense that it would give us a true competitive edge for a significant period of time? The answer to that question is complex and is, to my mind, treated in some measure by S.970. It is complex because it deals with developing a synergism--a set of players, ideas, and efforts that are much more than the sum of parts.

We have, in the United States, all of the elements of this synergism:

- A productive farm establishment.
- Major agribusinesses producing seeds, agrichemicals, and farm machinery and processing crops into products.
- A research establishment in agronomy, botany, plant physiology, and genetics that is arguably second to none.
- And one big new kicker. We lead the world, at present, in a new set of skills: bioengineering. Bioengineering enables us to move biological capabilities, thus creating crops with new economic potential, and to amplify biological capabilities, thus making that which is rare into that which is common.

What we need to do that others may not be able to do is to take these four strengths and use them to first develop and then deploy crops and/or processes that will result in new and large ranges of products. The new products will not easily be duplicated by others for some period of time; the large ranges of products will give American farmers a graceful plenty of choices on what to grow and who to grow it for.

And that's where consortia become key. No single American institution has the research staff and tools, the economic and agribusiness sense, and the knowledge of American agriculture to produce the required miracles. Consortia that combine all of the best that we may have to offer just might do it; they might provide the synergism that will take a powerful set of parts and convert it into an even larger whole. S.970 seems to call for the creation of such consortia.

At the moment, we are not alone in trying to use biotechnology to develop new agricultural products and processes. Although specifics seem hard to come by, it appears that the European nations—individually through new research programs in, for example, France, Britain, Italy, and Germany, and collectively through Project Eureka—are funding and performing relevant sorts of research. So, it would appear, are the Japanese and other Asian nations. What our competitors appear not to have done quite yet is put all of the required parts together: traditional crop sciences plus agribusiness plus biotechnology. We might be able to do that, given proper tools and incentives like S.970.

Some two years ago, a number of universities, research institutes, and agribusinesses joined to develop the Midwest Plant Biotechnology Consortium. The universities and research institutes (Exhibit 1-A) represent those with expertise in plant sciences and in molecular biology, biotechnology, and biochemistry as it might apply to agriculture. The corporate members (Exhibit 1-B) include representatives from sectors of agribusiness that are important now and may be even more important in the future. Corporations in seeds, agrichemicals, farm equipment, crop processing, and foods are involved, as are companies producing bulk and fine chemicals, fuels, pharmaceuticals, and diagnostics. Corporations range in size from Fortune 100 to small businesses. Most of the members in the Consortium are based in the midwest and have some stake in midwestern agriculture--an enterprise that is unique, as is all agriculture to its particular set of climactic, geographic, and economic determinants.

The Consortium held a workshop in December of 1985. During this meeting, some 70 industry representatives, in concert with 80 university participants, defined needs in agribusiness that, if filled, might lead to the development of new technologies. University staff members described research programs that might satisfy these needs. Throughout the workshop and subsequent deliberations, the intent was to place basic research in the context of industrial needs and to develop specific research programs that could be the basis for technology transfer and new technology development. The Proceedings of the Workshop (Exhibit 2) have been and will be used as major criteria for these actions. Industrial review of proposed work has been and will continue to be the basis for determining relevance of effort to new process and product development. Peer review will be the criteria for determining quality. Bills like S.970 could be the cement for putting the enterprise together.

(Attachment follows:)

EXHIBIT I

Midwest Plant Biotechnology Consortium
List of Participants

A. Research Institutes

Argonne National Laboratory
Michigan Biotechnology Institute

Universities

University of Illinois
Indiana University
Iowa State University
University of Iowa
Michigan State University
University of Minnesota
University of Nebraska
Northwestern University
Ohio State University
Purdue University
Washington University (St. Louis)
University of Wisconsin

B. Companies

Abbott Laboratories
Agracetus
Agrigenetics Advanced Research Div.
Amersham
Amoco
Anheuser-Busch Companies, Inc.
Archer Daniels Midland
Asgrow Seed
George J. Ball, Inc.
Cargill
ConAgra, Inc., Central Laboratory
Dean Foods
Deere and Co.
DeKalb-Pfizer Genetics
Dow Chemical
Fermco Development
FMC Corp.
Funk Seeds International
General Mills
Griffith Laboratories USA
International Minerals & Chemical
Kellogg
Kraft

EXHIBIT 1

B. Companies (cont'd)

Eli Lilly
Lubrizol Enterprises
Miles Laboratories, Inc.
Monsanto
National Starch and Chemical Corp.
Pillsbury
Pioneer Hi-Bred International
Quaker Oats
Sandoz Crop Protection Corp.
Sara Lee Corp.
A.E. Staley Manufacturing
Stauffer Seeds
Travenol Laboratories
United AgriSeed

DRAFT FOR REVIEW
February 21, 1986

EXHIBIT 2

THE MIDWEST PLANT BIOTECHNOLOGY CONSORTIUM

Proceedings of a Workshop
Held
December 10-11, 1985

EXECUTIVE SUMMARY

The industries involved with the processing of crops to foods, seeds, fuels, commodity chemicals, and pharmaceuticals have a number of common elements, e.g., the growth of plants, the storage and transportation of plant materials, and the general process characteristics of such materials. They all utilize what is in large measure mankind's major renewable resource; solar energy trapped through the processes of photosynthesis. They share many common concerns, problems, and opportunities.

A coordinated basic research program that examines each aspect of the process through which raw plant materials become commercial products can be developed. This program should address industrial problems and provide industry with knowledge and methodologies leading to new commercial opportunities.

This report describes problems and opportunities in agribusiness, as well as basic research programs that may contribute to the resolution of existing problems or the development of new opportunities. This presentation is the result of a two-day workshop, involving major midwestern universities, research institutes, and midwestern companies. The workshop was the first element of an experiment in technology transfer called the Midwest Plant Biotechnology Consortium, which will involve the eventual development of research programs at participating institutions, the transfer of results to midwestern industries through traditional and proven means of technology transfer, and the participation of the federal research establishment (again, through traditional means and mandates). The recommendations of this workshop would lead to a substantially increased basic research program in areas key to the commercial development of plant biotechnology; genetics, biochemistry, growth regulation. It would result in a high degree of cooperation between midwestern universities, research institutions, and industries. It would provide increased training for scientists in plant biotechnology; providing disciplines and capabilities in demand by the agribusiness community. By dramatically increasing the exchange of information between the basic research community and industry, the proposed effort might lead to more facile development and utility of projects/results of practical significance. If successful, work of the consortium should result in new processes or products and better or more-competitive methods for production of existing products, and thus economic growth for the midwest and the nation.

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L. INTRODUCTION

In July 1984, Argonne National Laboratory (ANL) hosted a workshop to consider potential research areas in the field of biotechnology of interest to the Department of Energy (DOE), its prime sponsor, and to the nation. Participating in this workshop were representatives of DOE offices and research scientists from industry, national laboratories, and universities. The general consensus from the meeting was that a planned, coordinated basic research program on the biochemistry, physiology, molecular biology, and biophysics of plants could make major contributions to commercial biotechnology in areas of interest to the DOE, other industries, and federal agencies.

Following the workshop, ANL initiated an experiment in technology transfer called the Midwest Plant Biotechnology Consortium. Given the key role of agriculture in the midwestern economy and the long record of interactions between midwestern research institutes and agribusiness, the midwest appeared to be the appropriate place to begin this initiative. A number of midwestern universities and industries with a variety of interests in plant sciences were contacted and asked to participate in the endeavor, to be based on the following principles:

- Technology transfer can be more easily effected if all partners in the transfer use practices familiar to them in the development and implementation of research programs and in the transfer and use of results.
- Research in such an effort must be both potentially germane to commercial needs and technically excellent. Thus, review of proposed work should involve both industrial and scientific peer review processes.
- Efforts should be scheduled over a five-year period and then evaluated. Program funds should be used primarily for the training and support of students, research fellows and other technical staff as appropriate; not for facilities or major capital equipment.
- Research participants would "own", according to their institutional practices, rights to intellectual property. Industrial participants would have access to the first disclosure of information. Further development would require negotiation, according to customary industrial practices, with the research institution.
- Given the high risk of basic research and the inherent difficulties in capitalizing upon returns from basic efforts, governmental agencies were considered to be the most appropriate funding sources and administrators of this initiative.

All of the universities and industries contacted were interested in the concept and agreed to participate in a workshop to define (a) industrial problems that might

benefit from research in plant-based biotechnology and (b) basic research that might lead to solutions to these general problems. (See Table 1 for a list of participants.)

The workshop was held on December 10-11, 1985; this report summarizes the proceedings. During the two days of deliberations, small groups of scientists from industry, academe, and research institutes first discussed problems and commercial opportunities for companies that process or are involved in the production of plant materials. They then discussed basic research that might lead to solutions of problems or to the development of new opportunities for midwestern agribusinesses. In many cases, industrial problems are indicative of gaps in basic knowledge in areas of potential commercial opportunity; thus, overlapping often occurred between the two days of discussions. In some cases, needs for the development of specific methodologies were identified, again resulting in some overlapping discussion. In a general sense, the workshop operated on three major themes:

1. Plants/plant derived materials can be used more efficiently or in new ways as renewable sources of food, fibers, chemicals, and pharmaceuticals
2. New/more efficient agriprocesses will be of major economic benefit to the midwest since crop-based industries are major factors in the present economic health of the region.
3. Midwestern institutions-universities, research institutes, industries, have the staff, facilities, and intent to carry out an accelerated program of basic research, development, and commercial deployment of plant-based biotechnology.

It thus appears that an integrated basic research program at major midwestern universities and research institutions, capable of transfer to midwestern agribusiness through available methods of technology transfer, can contribute to new commercial developments and thus to the economic well-being of the midwest and the nation.

TABLE 1. List of Participants

Research Institutes

Argonne National Laboratory
USDA - Northern Regional Research Center

Universities

Indiana University
Iowa State University
Michigan State University
Northern Illinois University
Northwestern University
Ohio State University
Purdue University
University of Chicago
University of Illinois
University of Iowa
University of Michigan
University of Minnesota
University of Wisconsin
Washington University (St. Louis)

Companies

Abbott Laboratories
Agrigenetics Advanced Research Div.
Amersham
Amoco
Archer Daniels Midland
Asgrow Seed
George J. Ball, Inc.
Beatrice Co.
BW Biotec
Cargill
Dean Foods
Deere and Co.
DeKalb-Pfizer Genetics
Dow Chemical
Fermco Development
FMC Corp.
Funk Seeds International
General Mills
Griffith Laboratories USA
International Minerals & Chemical
Kellogg
Kraft
Eli Lilly
Lubrizol Enterprises
Monsanto

TABLE 1. (Cont'd)

Pillsbury
Pioneer Hi-Bred International
Precision Laboratories
Quaker Oats
Sara Lee Corp.
C.D. Searle
Smith Laboratories
Sohio
A.E. Staley Manufacturing
Stauffer Seeds
Travenol Laboratories
Velsicol Chemical

II. OPPORTUNITIES IN PLANT-BASED TECHNOLOGY

A. FOODS

The food industry can be divided into three overlapping constituencies (consumers, food processors, and farmers) with similarities and differences in terms of perceived problems and research needs (Table 2).

Consumers, whether gourmets or retail marketers, are concerned with issues such as taste, color, shelf life, texture, consistency in quality, and cost. Little is known about the biochemistry of natural compounds responsible for flavor or color or the biochemical basis of texture in raw and/or processed foods. For raw fruits and vegetables, quality, like availability and cost in some instances, is a function of season and growth conditions; in addition, for processed foods, process conditions and chemistry contribute to quality. During storage, raw and processed foods may change in flavor, color, and texture, with changes occurring that may increase or decrease consumer acceptance. The chemistry of these changes (desired compounds undergoing synthesis, then metabolism to new, perhaps less-desirable compounds) and the biology of changes (fungal and bacterial growth resulting, in some cases, in the production of toxic compounds) are not as easy to control as one would desire.

Color and flavor are qualitative and quantitative functions of multiple compounds and their interactions. For example, the composition of volatile oils in black pepper, the level of methyl anthranilates in grapes, and the concentrations of specific sugars (fructose, sucrose, and glucose) in fruits all play key roles in flavor. Optical isomerization of a single chemical entity can radically alter flavor (e.g., D-carvone is responsible for flavor in dill and caraway, L-carvone for flavor in spearmint). Sugars may be converted to starch or to other sugars with commensurate changes in taste. Exposure to ethylene (either artificially introduced or naturally produced) will alter color and taste -- in some cases at the wrong time and place. The texture of plant foods is, in part, a function of the protein, lipid, and polysaccharide (e.g., pectin, lignin) composition of the plant. However, for either processed or unprocessed foods the relationships among chemical composition, cellular/tissue localization of various compounds, and desired textural properties are not clear.

Flavor, color, texture, and nutrition determine food quality: all can be radically altered by shelf storage. The qualitative and quantitative composition and the nature and interplay of enzymes such as proteases, pectinases, lipoxygenases, lipases, and amylases in foods are not well understood and are thus not amenable to economical control. The growth of microorganisms on stored plant materials, with occasional production of toxicants such as mycotoxins, is also affected by shelf storage and storage conditions.

Many of the desired (and undesired) properties of plant foods are altered through processing by drying, freezing, or cooking or by chemical extraction or selective hydrolysis of macromolecules. The complexity of interactions between plant components is such that processing to improve one plant property (e.g., taste) often results in the loss of another (e.g., nutrition).

TABLE 2. General Issues in Foods

Constituencies	Concerns
Consumers	• Availability • Taste • Nutrition • Consistent quality • Shelf life • Texture • Cost
Food Processors	• Tissue composition • New starch uses • Waste utilization/detoxification • Delignification • Crop storage • Appropriate availability of materials • Consistent Quality • Profitability
Farmers	• Crop yield • Chemical needs - fertilizers - herbicides - pesticides • Variability of desirable properties for a given crop - within companies - from company to company - export market versus import market • Market stability (contract farming) • Profitability

In addition to the concerns of the consumers (which influence consumer demand), the food processing industry must consider profitability. Thus, it must consider purely economic issues as well as the technical issues that determine qualities and quantities of its products. Among these issues are (a) the infrastructure involved in the selection, purchasing practices, shipping, and storage of its raw materials; (b) the capital investment in processing facilities; (c) the marketing and distribution systems for its products; and (d) the nature of consumer preference vs. other benefits/costs that might be associated with a given product. For example, a high-starch corn of high production cost, which could not be readily stored in existing facilities and/or could not be milled through existing facilities, would be of little present commercial value.

New plant materials for food use should, as much as possible, fit within the existing economic infrastructure for the use of plant materials. They should be able to be processed through existing technology and should be stable in terms of their composition as it affects product quality and processing variables. More important for many agribusinesses is the availability of consistent raw materials. It is claimed that such materials could eliminate in some food-processing industries up to 50% of the costs of equipment and facilities. The composition of the raw materials should be such that similar mixes of products can be derived (the new material fully replaces the old material and does not have to be purchased in addition to the old material). As much as possible, the new material should use existing systems for the purchase, transport, and storage of raw materials and product.

The midwestern food processing industries utilize a range of crops to produce their products. New crops or new cultivars may be needed to open new markets; these new crops or cultivars may become important because of changes in agripactice (e.g., differences in regional water availability could increase production of certain cereals such as wheat, barley, or oats in the midwest).

To illustrate the general nature of issues that concern the food processing industry, workshop participants discussed potential requirements for two widely processed crops, corn and soybeans.

A general list of requirements can be derived for corn to be processed to oils or syrups (Table 3). However, one corn-processing company attempted to define the properties of one ideal corn kernel for all its uses and could reach no consensus. Requirements vary depending upon corn use (cereal manufacturers require corn with different characteristics than that required by corn oil or corn syrup producers) and upon national preference (corn for export market will have different properties than that for domestic use). In general, high starch content is desirable since it allows increased productivity of a given plant processing corn to corn syrup without increasing facility size and thus capital investment. Since wet-milling is an energy-intensive process (the third most energy-intensive industry in the U.S.), corn seeds with low, stable water content are of general value. Storage properties of corn -- particularly fungal resistance -- are of general concern.

Stability of seed composition, from season to season and supplier to supplier, is extremely important. Control of the enzymes or proteins of corn that permit constant processing conditions would be valuable. For example, control of seed moisture level

TABLE 3. Requirements for Corn to be Processed to Oils or Syrup

-
- Fast maturation
 - High sugar content that changes slowly to starch
 - Low blanch temperature or low concentration of degradative enzymes
 - Controlled concentrations of starch/oil/protein with levels that stabilize quickly
 - Fast field drying (gets to 18-22% moisture content)
 - Separability
 - High endosperm content
 - Low oxidative rancidity
 - Coproduct reduction
 - No requirement for steeping
 - Well-characterized gluten (protein) with new uses
-

could eliminate or lower the need for steeping; quantitative and qualitative control over starch compositions would decrease variability in starch processing. Control over oil composition or the enzymes involved in fatty acid degradation could decrease spoilage losses and lower process variability in oil extraction.

As would be expected, the requirements for corn to be processed to cereal (Table 4) are somewhat different from those described for corn to be processed to oil or syrup (Table 3). Changes in properties of corn kernels during storage with concomitant changes in product quality are of more immediate concern, as are all parameters that would affect corn taste (given that the product is essentially the processed seed). At present, a cereal manufacturer using corn presently cropped in the U.S. will obtain less useable material than from corn available in Argentina.

The requirements for oats used in cereal production (Table 5) differ slightly from those for corn. In particular, changes in oat proteins and polysaccharides that might lead to better baking properties represent a different need; new uses for waste materials, resistance to oat seed breakage, and control of lipid composition were all also mentioned as needs for oats.

Needs for soybean seed are presented in Table 6. Properties that affect taste, digestability, nutritive value, and processing variability/costs are highlighted. Table 7 presents general requirements for other crops that may be processed.

**TABLE 4. Requirements for Corn
to be Processed to Cereal**

-
- Clean breaking hull
 - Lesser oil oxidation
 - High endosperm content
 - Easily separable starches
 - Low oxidative rancidity
 - Excellent storage properties
-

TABLE 5. Requirements for Oats

-
- Improved baking characteristics
 - Ability to control lipid content and lipid degradation: decrease rancidity
 - New use for oat hulls (30% of seed weight)
 - Lowered resistance to breakage: improve milling properties
-

TABLE 6. Requirements for Soybeans

-
- Elimination of stachyose, raffinose, and lipoxidase
 - Reduction in levels of trypsin inhibitors
 - Ability to control blend of amino acids in bean protein and provide higher methionine levels
 - Easier extraction of lecithin
 - Removal of chloracetic acid
 - Ability to control oil/protein ratio
 - Ability to control oil ratio of saturated vs. unsaturated fatty acids
 - Ability to control enzymes that alter flavors
-

TABLE 7. Requirements for Vegetables and Other Crops

-
- Low blanching temperatures/no blanching
 - Rapid maturation to stable properties; e.g., sugar to starch conversion
 - Insect resistance
 - Red wheat bran with characteristics of white wheat bran
 - Increased understanding of developmental biology of seeds and fruits
 - Knowledge of kinetics, mechanisms, or processes in ethylene biosynthesis and induced ripening
-

Throughout the food processing industry, there is a need for increased knowledge of and use of enzymes to make specific products. Enzymes of greater thermostability, enzymes active at low temperatures and thus able to function in processes without adding heat, and enzymes capable of serving as catalysts through more useful or broader ranges of pH are seen as needs. More specifically, enzymes (e.g., amylases) capable of higher rates of starch degradation or/and of producing new products from starch or capable of degrading a greater range of polymers to new products or feedstocks under conditions of commercial value (e.g., ligninase) may be important.

Consumer and processor preferences guide agricultural practice as well; the farm community, however, has an additional set of concerns. As with any industry, profitability is an important consideration; thus, changes in cultivars that require purchase of new capital equipment will be resisted, as will changes in the economic structure of farm practice (e.g., cultivars that give lower yields, given existing economic infrastructure, may not be grown even though they may possess other attractive properties). Since yield is of major importance, there is obviously great interest in increasing the levels of useful plant material and minimizing waste. For example, control of pod abscission in soybeans might result in a 20% increase in bean yield in a given area. As increased regulation and ground water contamination affects useage of pesticides, herbicides, and fertilizers in agriculture, there will be a continuing need for new methods or materials to replace those existing. Finally, and perhaps obviously, the ability to control and regulate plant growth under conditions of uncertain precipitation, temperature, or nutrient availability would be most welcome.

B. SEEDS

The seed industry has two sets of specific needs. One set is defined by the growers and processors of crops, the other by needs inherent in the production, dissemination, and storage of seeds for crop production. A great degree of overlap exists between these needs since seed crops such as corn, soybeans, and oats present similar

difficulties or opportunities whether they are viewed as seeds, products, or sources of products. For example, issues such as storage properties and pest resistance affect both seed producers and users. Other needs such as a requirement for a high rate of germination in the field and the ability to maintain stable genetic traits over prolonged periods of plant breeding are primarily concerns of commercial seed producers.

In addition, there may be some antagonism between needs for certain users of seeds vs. needs for seed producers. For example, lowering seed protein and increasing seed starch may be of economic benefit in starch or sugar syrup production. On the other hand, a change that affects storage proteins or saccharides may cause unacceptable germination properties.

We have not attempted to differentiate between these two sets of needs nor to describe, in any depth, the synergisms/antagonisms that these needs may pose across technological lines. Table 8 describes general needs and provides a limited number of specific examples. Because of the nature of seed production, we listed a large number of requirements for the development of data bases and specific methodologies (parts A-E of the table). The needs for general seed properties related to product quality are listed in part F of the table.

C. AGRICHEMICAL TECHNOLOGY

Industrial needs for agrichemicals (pesticides, herbicides, and nutrients/other agents added to crops to facilitate plant growth or the development of desired traits) can be divided into three areas: product development, product use, and product disposal (Table 9).

To develop new products (Table 9), we must understand the mechanisms by which pesticides/herbicides effect desired actions. For example, an understanding of these processes may permit the development of agents that become effective only after metabolic activation in the target organism and are environmentally 'inert' until activation occurs. Commensurate with this need, systems for the analyses of pesticide/herbicide potential that can supplant expensive and time-consuming whole-organism studies are required. Such systems may use knowledge of targets of action (e.g., assays of receptor/key enzyme inhibition). Since an ideal agent for control of weeds or insect pests should persist in its target organism for as long as possible, an understanding of the metabolism or detoxification of pesticides or herbicides would be of use. Persistence of pesticides or herbicides in soils or other field milieu without substantive effect on desired organisms is a major desired property for new products.

New products to increase yields or aid in the development of desired traits will require data and analyses correlating levels of these materials with desired agronomic traits. For pesticides or herbicides, the ability to target these materials to specific crop without affecting other ecosystems or agricultural practices is important.

Pesticides, herbicides, fertilizers, or other materials added to crops for animal or human consumption pose sets of needs contingent upon product use (Table 9). Information on toxicity, persistence in soil, and rates of transport/transformation in soil, ground,

TABLE 8. Seeds

Need	Example
A. A basic understanding of the molecular mechanisms underlying and controlling agronomically important traits	- Stress tolerance - Reproductive biology - Seed quality - Plant development - Gene regulation - Developmental genetics
B. An effective gene transformation systems	- Genetic movement and expression of single genes, polygenic traits, and novel genes for monocotyledons as well as dicotyledons.
C. Environmental and biological stress systems for agronomic application	- Stresses such as salt, pH, drought, temperature, diseases, and insects
D. Plant propagation and regeneration systems for <u>in vitro</u> products	- Somatic embryos - Protoplasts - Cell fusions - Single cells - For mutant isolation: • selection systems for single traits • asexual propagation
E. Generation of exotic germplasms by "wide crossing"	
F. Improved product quality	- Germination • fast • uniform • high rate - Good yield response to fertilizer with more efficient utilization of K, P, etc. - Control over major seed components of commercial value (starch, protein) - Moisture and drying characteristics of seed products: fewer cracks and splits in seeds - Inborn fungal and insect resistance

TABLE 9. Needs in Agrichemical Industry

Product Development

- Identify targets of pesticide/herbicide action
- Develop innovative, inexpensive screening assays for pesticides and herbicides
 - tissue culture
 - receptor attachment
- Determine pathways in target organisms leading to metabolic inactivation of herbicides and pesticides
- Develop plants with resistance to specific insect pests
- Control persistence of pesticides, herbicides, or applied fertilizers
- Correlate tissue analyses of micronutrients with economically important agronomic traits

Product Use

- Develop methods which quickly, inexpensively, and effectively screen for toxicological potential of herbicides/pesticides
- Provide systems that allow effective modeling of transport, or transformation and thus movement of pesticides, herbicides, or fertilizers through the environment
- Develop management practices, measuring, modeling and application technologies that allow optimal delivery of herbicides, pesticides, or fertilizers
- Develop herbicide resistance in commercially important plants
- Determine agrichemical properties or problems for crops other than soybean and corn

Product Disposal

- Develop acceptable methods for detoxifying or disposing of agricultural and agrichemical wastes
 - Develop "inactivators" to destroy or remove pesticides or herbicides before human or animal consumption
 - Model disposal in all relevant milieu of microbially based pesticides, herbicides, or other agrichemicals and determine potential impacts
-

surface waters, and sediments is needed to develop systems that will deliver optimal concentrations of nutrients, pesticides, and herbicides and pose minimal risk to environment and workforce. In this regard, cultivars that are resistant to herbicides or possess innate resistance to specific insect pests would allow better management of agrichemicals. Within the midwest, new crops for new applications in food, pharmaceuticals, fuels, and chemicals will require development of new agrichemical agents, procedures, and practices if high yields and desired characteristics are to be obtained.

Increasingly, the disposal of agrichemical residues has become a matter of concern (Table 9). Economically viable methods to detoxify agrichemical residues in fields, ground waters, and products prior to consumption need to be developed. Analyses of new forms of agrichemicals relative to their degradation, lifetimes, and potential environmental effects, as well as their effects on crops other than targeted crops are now important because of public and regulatory concern.

D. FUELS/INDUSTRIAL CHEMICALS

Plant materials have been widely used either directly or after appropriate biological or chemical conversion as sources of fuel, fibers, and commodity chemicals (e.g., ethanol and industrial solvents such as acetone or butanol). In recent years, biomass has been suggested as another source of these commodities, but the economics of such use, overall, have not been favorable. For workshop discussion, the process of converting plant materials to these bulk commodities was divided into four elements:

1. Production of plant tissue
2. Harvesting and storage
3. Processing
4. Marketing and distribution

Table 10 summarizes the area of production of plant tissue. In general, factors that would result in higher yields of biomass/unit investment or of economically useful yields of biomass from marginal lands (e.g., little capital investment in land) were of interest. Development of plants that could be easily used as alternatives to traditional cultivars such as corn, soybeans, etc., under economically favorable conditions appears valuable, especially if the infrastructure (e.g., harvesting, storage, shipment, processing) for their use could involve existing practices for current crops as much as possible.

Changes in plant composition resulting in materials requiring little processing to product would obviously be of great economic benefit. These changes might be directed towards producing a high yield of a specific chemical entity or to increasing the use or processing of a product by changing the chemical composition, structure, or concentrations of a material currently produced by plants.

TABLE 10. Production of Plant Tissue

Needs	Specific Examples
• Increased yield	Enhanced stress tolerance (water, temperature)
• Ability to use marginal lands	Poplars, locusts, shrubs
• Fuels, chemicals, or fiber producers as economically viable alternative crops	milkweed, guayule, jojoba
• Materials in plant closer to material used by processor as product	- More/less lipids, oils, sugars; less/more starch - Increased/decreased amounts of cellulose/lignin - Direct commodity production (adipic acid, glycerol) - Fatty acid composition more amenable to use/processing to diesel fuel - Byproducts of greater commercial value (e.g., wastes, pigments)

For a given use, maximum economic benefit may involve coprocessing of byproducts, and major product materials. This could provide greater value per unit measure of plant material.

Table 11 describes considerations relevant to the harvest and storage of plant materials for use as fuels or commodity chemicals. If process economics are to be reasonable, the crop must either be 'dense' in terms of desired material (i.e., must have high yield in small volume) and thus be easy to transport or involve processing equipment that can be easily used near producing farms. For process purposes, the crop must remain constant in desired properties during storage. To maintain constancy during storage, synthesis or degradation of plant material by plant enzymes and external pests such as insects and microorganisms must be controlled.

Requirements for the processing of plant tissue are given in Table 12. Control of fermentative processes and methods for economically useful separation, concentration, and purification of desired chemicals were discussed, as was the development of fermentative microorganisms more resistant to toxicants produced, either as products or byproducts, during fermentation. The utility of fermentative organisms immobilized to

TABLE 11. Harvesting and Storage

Need	Examples
• Favorable economics for transport and storage	- Processing facilities near producing farms - High concentrations of material/unit measure
• Consistency of desired properties in storage	- Elimination of enzymatic degradation in beets, alfalfa, soybean - Control of pests (insects, fungi)

TABLE 12. Plant Tissue Processing

Needs	Examples
• Increase carbon use	- Reduce CO₂ formation
• Control Processes	- Regulate inhibition or induction in fermentation processes - Increase resistance to toxicants produced during fermentation processes
• Develop high-efficiency processes for separation and purification	- Combine reactor/separator - Increase concentration in feedstocks
• Improve tissue culture procedures	- Form single product directly - Secretion of product
• Develop procedures for more-efficient product formation	- Develop better catalysts (e.g., enzymes modified ("engineered") for applications

support matrices and/or capable of accelerated secretion of products seems of concern. Plant tissue culture could be a useful technique if procedures were developed to produce economically useful concentrations of products in easily extractable forms. In addition, development of better catalysts (e.g., enzymes engineered through the process of site-specific mutation) was considered as a way to achieve more efficient (in terms of process kinetics and concentrations) formation of product.

In a technical rather than strictly economic sense, marketing considerations (Table 13) require the ability to easily identify pathways that might yield fuels or commodity chemicals in biota, especially if this capability could be coupled to data bases or analytic procedures describing genetic or regulatory processes for given pathways. These literature analyses would need to be accompanied by the capability to easily screen plant tissue or fermentation processes for the presence of a desired material. Given appropriate economic analyses of market, these considerations would demonstrate overall market feasibility.

E. PHARMACEUTICALS

For pharmaceuticals, needs (Table 14) centered around the development of systems that would allow facile assay for potential new pharmacological agents. This development would require analyses of the chemistry or therapeutic modality of existing agents derived from plant tissue. Since plant tissues are only selectively used as sources of pharmaceuticals, new methods of separation and purification of materials from plant tissue might be required, as would development of equipment, methods, or practices commensurate with scaling processes from bench to commercial practice.

This group felt that further basic research in a number of areas (to be discussed in Section III) of plant science would be required if plant systems were to be a major source in the manufacture of pharmaceuticals.

TABLE 13. Marketing and Distribution

Need	Example
• Identification of target processes	- Automated systems for screening pathways
• Availability of capabilities for analyses or screening of plant products	- Rapid, on-line organic analytic methodologies

TABLE 14. Needs in Pharmaceuticals

Needs	Specific Examples
Identify and characterize materials of pharmacologic value	- Diagnostics (lectins, glucose oxidase, peroxidase) - Therapeutics (cardiac glycosides, vinca alkaloids, antibiotics, carrier molecules such as ricin, abrin which can be combined with tumor-targeting moieties) - Nutritional supplements (amino acids, glucose)
Develop new assay systems to identify pharmaceuticals	- <u>In vivo</u> (epidemiologic and anthropogenic) - <u>In vitro</u> (genetic effect, neuro-activity)
Develop new purification and separation systems	- Affinity columns - Immunoaffinity (poly- and monoclonal antibodies) - High-pressure liquid chromatography
Develop and scale-up macrosystems to produce pharmaceuticals of plant origin	- Appropriate economic analyses - Evaluation of closed system (lab) vs. open (commercial) - Evaluation of continuous vs. batch systems - Development and deployment of specialized fermentors - Regulatory/governmental issues

III. BASIC RESEARCH PROGRAMS TO ADDRESS OPPORTUNITIES IN PLANT-BASED TECHNOLOGY

A. "GENERAL" VS. "SPECIFIC" RESEARCH

The path to use of plant materials for industrial or commercial purposes is outlined in Fig. 1. An analysis of industrial problems and opportunities permits us to categorize elements of this path as general (applicable to all plant-based industry) or specific (applicable primarily to a specific industry). We used this pathway as a tool in discussing the basic research required to effect solutions to the problems presented in the previous section. "Specific" is defined in relative terms for our purposes. In some cases, the required research, if performed, could apply to needs in more than one area. In those cases, we have arbitrarily defined the requirement as either "specific" or "general" depending on where it fits best.

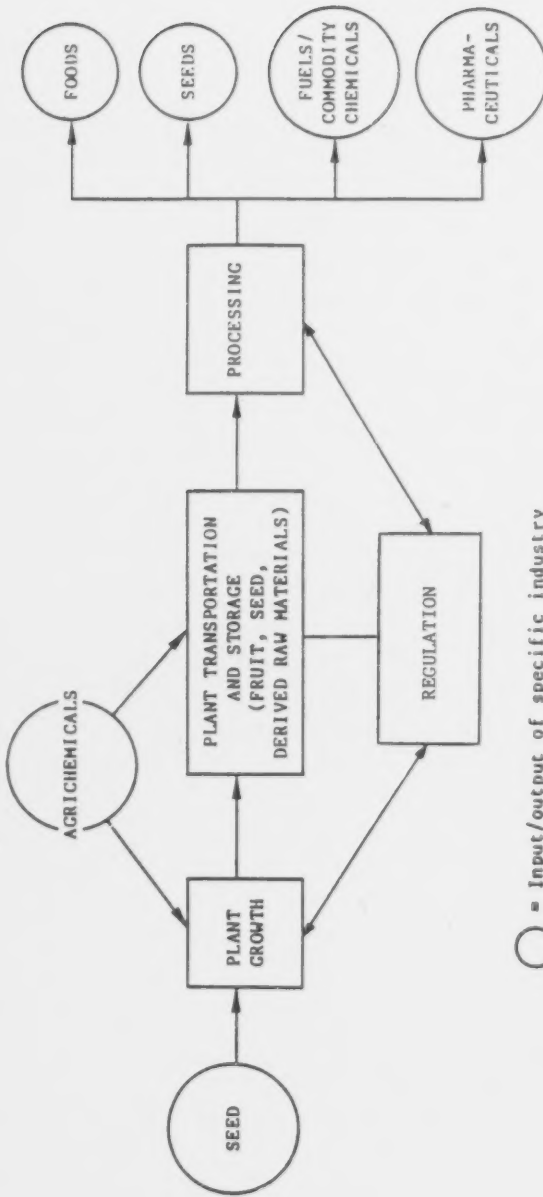
Research requirements are defined by the elements of the pathway given in Fig. 1 (Table 15). Before beginning a more detailed discussion of these requirements, we considered a set of basic research requirements that appear to address essentially all elements of the production of plant tissue for use as industrial commodities (Table 16).

It should be recognized that plant biotechnology, if it is to be of commercial use, must possess the broadest knowledge of the biological and chemical capabilities within the plant kingdom. Before transferring genes, one should have some strong sense as to what might be worthy of transfer. Further, one should be capable of applying the knowledge gained to as many cultivars of commercial value as possible. Both basic and applied research scientists agreed that well defined libraries, as inclusive as presently possible, of information; and banks of organisms and structural and regulatory genes (commensurate with needs for protection of proprietary rights) are required to address all research requirements. Also required are the establishment of systems for tissue culture and genetic transformation and the development of vectors for exchange of plant genetic material. It appears, perhaps for all biotic systems, that there is little useful understanding of the operation and genetic base for multienzyme systems required to affect the synthesis of cellular macromolecules or provide energy and metabolites for cell growth. In this context, the complex process of plant embryonic development -- from seed to plant to seed -- is poorly defined; thus the "site" for action of genes added through biotechnological processes may not be defined or controlled during the course of plant development.

Although not specifically discussed at the workshop, recent events suggest that research which either will lead to effective regulation of plant-based biotechnology or that can address present concerns and regulatory/judicial practices will be of general interest to all of the agribusiness community.

B. RESEARCH RELEVANT TO SEEDS

Table 17 defines a basic research program of potential use for seed production. The process of germination (biochemistry, physiology and genetics) should be considered



○ = Input/output of specific industry
 □ = General input/output needs of plant-based industries

FIGURE 1 General Path for Industries Involved in Production/Processing Plant Materials

**TABLE 15. Areas with Requirements
for Basic Research**

-
- Seeds
 - Plant Growth
 - Agrichemicals
 - Transportation and Storage
 - General plant tissue processing
 - Foods
 - Fuels
 - Pharmaceuticals
-

TABLE 16. General Basic Research Needs for Plant Biotechnology

-
- Libraries; Banks; Data bases of/on organisms, cells, genes for range of purposes
 - Tissue culture techniques, transformation systems, and genetic vectors for monocotyledons/dicotyledons
 - Understanding of the genetics and regulation of multi-enzyme systems
 - Understanding the biochemistry and mechanisms of action of growth regulators and their receptors.
 - Analyses for embryonic/morphologic development
 - Understanding of basic biological or biochemical capabilities in plant species
 - Development of systems/practices/data bases that can aid in reasoned and effective regulatory practices for plant-based biotechnology
-

TABLE 17. Basic Research Needs in the Area of Seed Production

-
- Define traits of agronomic and industrial importance
 - Provide gene/seed/embryo libraries and banks of material
 - Develop complete understanding of germination
 - Storage materials and their use
 - Pathways of differentiation
 - Properties of early embryonic tissues
 - Develop systems to provide seeds or appropriate embryonic material from tissue culture cells or other in vitro preparations such as cell fusions, protoplasts, etc.
 - Generate systems to permit "wide crossing" of present cultivars with ancestral species, present cultivars with remote species containing desired traits
 - Understand the expression and regulation of polygenic traits
 - For all of the above, develop model systems that will correlate with most important agricultural crops
-

in depth. Methodologies should be established to permit the development of seeds or other appropriate preparations of embryonic tissue from tissue culture or a range of cellular systems. This effort should be performed with plants of economic importance or with model systems which may be extrapolatable to agricultural cultivars. In essence, this type of effort may require a variety of comparative studies with a range of plants, both those currently in agricultural use and those with properties that might be of benefit in the development of new types of plants or seeds.

To acquire appropriate genetic diversity in the face of shrinking numbers of wild species, it appears important to develop systems that will allow the sequestering of genes, regardless of source, in relatively well-understood cultivars. Perhaps more than in other fields of plant-based commercial endeavor, the production of seeds requires a knowledge of desirable traits and banks of materials that may contain such traits. One must develop and maintain the widest possible degree of genetic diversity through the proper exploitation of the existing plant gene pool.

C. RESEARCH RELEVANT TO PLANT GROWTH

Ideally, plant-based industries may want to control plant growth such that useful cultivars grow under a wide range of regimes of soil, nutrient, and climate, at controlled rates appropriate to process needs rather than to season, and with full control of

composition of plant tissue. Basic research that may contribute to creating this idyll is described in Table 18. If this ideal situation is to be approached, it will require full understanding of how plants derive their nutrients, how nutrients and essential factors for growth are transported through the growing plant tissue, and how hormones or growth regulators effect their action. Knowledge of the relationship of plant to soil or soil processes and an understanding of environmental stress in plants differing widely in terms of their abilities to withstand stress or grow in soils differing in composition, available nutrients, and microbial communities would also appear needed.

TABLE 18. Basic Research Needs in the Area of Plant Growth

-
- Understand processes of photosynthesis and distribution of fixed carbon to tissues/plant components
 - Elucidate pathways for nitrogen, phosphorus, and sulfur utilization relative to synthesis and degradation of amino acids and purines and pyrimidines
 - Identify paths for intracellular/tissue transport of proteins and metabolites in growing plants
 - Analyze synergisms between plant and soil biological and chemical processes (rhizosphere dynamics)
 - Describe hormones and regulators involved in plant growth (their targets, and modes of action)
 - Define the physiology of stress (temperature, salinity, water deprivation, pollutants) on plant growth
 - Determine pathways for regulation of plant gene activity by environmental (e.g., light, nutrients) factors
 - Understand the materials, processes, and kinetics associated with plant cell wall and membrane formation
 - Define the morphology and physiology of plant differentiation from seedling to fruit
 - Develop systems that permit the identification, appropriate transfer, and expression for single genes or genes that function coordinately in monocotyledons and dicotyledons relative to plant growth defined in the above studies
 - Maintain libraries of genes, genetic regulatory elements, or species that may be of importance to research and development on plant growth
-

To "fix" and express desired traits at appropriate times, research on regulation of plant genes by environmental factors and by factors amenable to manipulation may be needed, as will knowledge of plant cell macromolecules and ultrastructure and their changes during the course of differentiation.

If the above information is to be of optimal use, traits of consequence must be coupled to appropriate systems of genetic transformation to allow movement and expression of a gene or of a complex of genes into commercially useful plant species.

D. RESEARCH RELEVANT TO AGRICHEMICALS

To develop new agrichemical agents, improve existing agents, or develop cultivars resistant to insects and/or microbial pathogens, research is needed to identify the nature of host/pest interaction. More effective practices relative to herbicides and pesticides will require knowledge of their targets and of their persistence in plant tissue, soil, and water. This base of information may allow the development of screening techniques to quickly identify compounds that may have herbicidal or pesticidal activity and useful properties of persistence, environmental transformation, and transport. Coupled with assays to quickly measure toxicity to higher organisms, these systems might allow for quicker and more economically effective selection of compounds of potential commercial value.

Research on the mobilization and transport of nutrients in a range of crop plants as a function of soil type and environmental milieu may permit the development of more effective forms and regimes for application of added nutrients.

A summary of required research is provided in Table 19.

E. RESEARCH RELEVANT TO PLANT STORAGE AND TRANSPORTATION

Plant tissues change during storage and transportation due to metabolic processes inherent in the tissue and to the action of external agents, some intentionally used (ripening agents, sterilants, etc.) and others found within the environment (saprophytic/parasitic microorganisms). The sum of these processes determines the storage characteristics of plant tissues; thus, an understanding of their basic characteristic (Table 20) may permit development of crops or conditions capable of longer storage life or of simpler processing for storage. For example, selection of cultivars with heat-sensitive biodegradative enzymes in fruits or seeds could result in a decreased need for blanching by heat prior to storage.

F. RESEARCH RELEVANT TO PLANT PROCESSING

Certain plant materials (e.g., starch, storage proteins, enzyme inhibitors, toxins) are of concern to a number of different agriculturally based industries, as are the properties of microorganisms, enzymes, and enzyme systems that might be useful in the controlled degradation of these materials and of their reformation into products. The

TABLE 19. Basic Research Needs for Agrichemicals

-
- Identify natural factors involved in plant resistance to insect pests and microbial and fungal pathogens
 - Isolate, characterize, or catalogue and develop a library of virulent and avirulent microbial and fungal plant pathogens, insect pests, insect predators, and microbial pathogens
 - Analyze targets for pesticide or herbicide action and factors involved in resistance
 - Determine pathways for degradation or detoxification of herbicides and pesticides in target organisms, soils, waters, sediments and cultivars
 - Develop cellular, tissue culture, or protein receptor screening procedures for pesticides and herbicides effective with monocotyledons and dicotyledons
 - Examine the comparative biochemistry of herbicides in plants of agricultural importance
 - Analyze mobilization and transport of nutrients from soil to plant
 - Determine genetics of plants, insects, or weeds relevant to all of the above and develop systems for appropriate gene amplification and movement
 - Develop libraries of organisms, structural and regulatory genes, and vector systems with application to agrichemical problems
-

TABLE 20. Basic Research Needs for Plant Transportation and Storage

-
- Analyze physiology, enzymology, and genetics of plant oil and protein, polysaccharide degradation
 - Determine nature of seed and fruit interaction with saprophytic and parasitic microorganisms
 - Understand physiology, biochemistry and genetics of processes of osmotic control, water loss and regain in seeds
 - Derive metabolic pathways and regulation for mycotoxins
 - Analyze biochemistry, regulation genetics of normal and chemically induced ripening
-

ability to enrich plant tissues, used as sources of a given product, in metabolites closer in chemistry to final product, is also of interest and will require a much greater understanding of the compartmentalization and utilization of primary plant nutrients, in addition to the development of methodologies for control of plant metabolism. A summary of basic research that may be of general concern in plant processing is provided in Table 21.

G. RESEARCH RELEVANT TO FOODS

The enzymology, physiology, biochemistry, and genetics of the plant materials responsible for taste, texture, color, and nutrition are obvious fields for basic research applicable to general problems in the food industry. Research relevant to the properties of enzymes that may be of use in food processing and their alteration to more closely fit process conditions is also of obvious use (Table 22).

TABLE 21. Basic Research Needs for Processing

-
- Examine chemistry, biochemistry, and physical properties of starch and relate this knowledge to plant physiology, biochemistry, and genetics
 - Determine chemistry, biochemistry, and physical properties of lignin, cellulose and other plant polysaccharides and relate this knowledge to plant physiology, biochemistry and genetics
 - Examine the chemistry, biochemistry, physical properties, and genetics of major classes of plant storage proteins such as gluten, gliadin, etc., and relate this knowledge to plant physiology, biochemistry and genetics
 - Determine the metabolism, biochemistry, and physical properties in plants and animals of enzyme inhibitors, surface-active agents (mitogens) and plant-synthesized toxins and relate the knowledge to physiology, biochemistry, and genetics
 - Analyze the enzymology, biochemistry, and genetics of degradation by mesophilic, psychrophilic and thermophilic microorganisms of starch, cellulose, lignin, and other plant polysaccharides and determine metabolism of sugars released by such degradation
 - Examine utilization or compartmentalization of photosynthate, nitrogen, phosphorus and sulfur
 - Develop regulatory genes that respond to light, heat, developmental and pathologic factors
-

TABLE 22. Basic Research Needs for Foods

-
- Examine the biochemistry, enzymology, and genetics of flavor, texture, and color in major food crops
 - Determine factors influencing fatty acid composition in major food crops
 - Examine the structure, chemistry, and activity of enzymes that might be used in food processing (e.g., proteases, oxygenases, amylases, etc.); in particular, perform comparative biochemistry relative to properties such as thermophilicity and stability at pH extremes
 - Examine proteins, carbohydrates, and lipids responsible for nutritive value in plant tissue relative to biochemistry, tissue differentiation, and genetics
 - Develop organism, gene, and data base banks
-

H. RESEARCH RELEVANT TO PHARMACEUTICALS

Purification of materials for use either directly as pharmaceuticals or as precursors for pharmaceutical production from plant tissue is, at present, neither simple nor inexpensive. Research on plant tissue culture or on plant mechanisms for compartmentalization or secretion of specific materials may yield methods resulting in materials of higher purity or specific concentration and thus of greater use in drug synthesis (Table 23).

I. RESEARCH RELEVANT TO FUELS/CHEMICALS

Basic research of potential use in the derivation of fuels or commodity chemicals from plant tissue (Table 24) may consider development of cultivars capable of growth under marginal conditions and plant biological or chemical attributes that might yield materials of more direct use (requiring less processing) in production of high-throughput, low-value products.

J. RESEARCH RELEVANT TO REGULATION

Increasingly, the safety of new technologies, have become matters of concern to the public, media, and government. To a certain extent, this concern develops irrespective of the nature of the technology. Synthetic fuel production, new pharmaceuticals, and all aspects of genetic technology are examples of such concerns. Recent events suggest that the lack of effective practices relative to public and governmental communication; the lack of effective and mutually agreed regulatory practices involving all interested parties (federal, state, local government, etc.) can stop

TABLE 23. Basic Research Needs for Pharmaceuticals

-
- Understand, at cellular level, processes of secretion and extrusion in plants relative to physiology, biochemistry and genetics
 - Study biochemistry, physiology, and genetics of vacuoles involved in storage, transport, and secretion in plants
 - Develop screening systems for analyses of plant primary and secondary products that may have diagnostic or therapeutic use
 - Develop range of plant tissue culture systems and develop manipulatable regulatory systems
-

TABLE 24. Basic Research Needs for Fuels

-
- Examine physiology, biochemistry, and genetics of plants (trees, shrubs) that can grow under marginal conditions
 - Analyze plant pathways leading to intermediates that may be of use in fuels or commodity chemicals; determine enzymology, regulation, and genetics
 - Examine secretion and vacuolization in plant cells and tissues
 - Develop plant tissue culture systems amenable to facile genetic or regulatory manipulation
-

the development and implementation of new, potentially beneficial and significant plant-based technologies. Basic research in this area should therefore (Table 25) consider better means of quantitative risk assessment coupled to an understanding of processes which can be used to more effectively communicate the results of such assessment. Methods should be sought which can control the growth/trait expression/proliferation through seeds of bioengineered cultivars to assure that bioengineered cultivars will only effect their wonders at the discretion of the technology user.

TABLE 25 Basic Research Needs for Regulation

-
- Development of improved methods of risk assessment
 - Analyses of traits and their regulation that may serve as basis for "safer" bioengineered plants (e.g., sterility genes, hypersensitivity to specific chemicals, environmental factors, etc.)
 - Greater public/media/governmental understanding of gene movement and trait regulation
-

Statement of Dr. B. R. Baumgardt
Director, Indiana Agricultural Experiment Station
Associate Dean of Agriculture
Purdue University
West Lafayette, Indiana

May 15, 1987

Before the

U.S. Senate Committee on Agriculture, Nutrition and Forestry

S.970 "Alternative Agricultural Products Research Act of 1987"

INTRODUCTION

Mr. Chairman, my name is Bill Baumgardt. I am Director of the Indiana Agricultural Experiment Station and Associate Dean of Agriculture at Purdue University in West Lafayette, Indiana. Also I am the immediate past-chairman of the Experiment Station Committee on Organization and Policy commonly known as ESCOP, the Committee which coordinates this nation's State Agricultural Experiment Station system. Since the Bill calls for the use of the tools of biotechnology, I also will mention that I am a member of the Committee on Biotechnology of the National Association of State Universities and Land Grant Colleges (NASULGC). I thank you very much for the opportunity to appear before you to testify in favor of this Bill which is one important component of a much needed overall thrust to improve the competitiveness of U.S. agriculture.

IMPORTANCE OF PUBLICLY SUPPORTED AGRICULTURE RESEARCH

The use of public funds to support agricultural research represents a wise investment for the U.S. taxpayer. The annual internal rate of return on past investments in agricultural research through the State Agricultural Experiment Stations and the USDA Agricultural Research Service has been between 30 and 60 percent per year. Public sector research has accounted for about one fourth of the total productivity growth in U.S. agriculture over the last four decades. It is interesting to note that for every \$1.00 of benefit acquired through research in a state or region, about \$4.00 in benefits spill over into nearby states and regions.

The high rate of return on the investment in agricultural research and other statistics are indicators that we are under-investing in agricultural research. Public sector investment in relevant agricultural research is about one percent of the total value added in farming. Also, it is important to note that those farmers and growers who quickly adopt appropriate technology benefit for their situation; however, all consumers benefit from this investment of public funds in the long run. In fact, public sector agricultural research tends to benefit lower income groups preferentially (since they invest a larger percentage of their income on food than do higher income groups).

This Bill addresses the most important issue facing this nation overall and agriculture in particular, that is, how can we regain our competitive edge. A recent OTA Report ("A Review of U.S. Competitiveness in Agricultural Trade, A Technical Memorandum" October 1986) noted that "research spending on agriculture is high throughout the world; indeed, the fraction of non-defense research spent on agriculture in Japan, France and several other nations

exceeds that of the United States." The National Science Foundation has summarized data which indicate that the U.S. must increase its investment in research and development if we are to enhance our competitiveness.

The authors of this Bill are to be commended for recognizing that the public has an important role in the funding of research to aid competitiveness. Some members of our society have erroneous views about the need for various kinds of research as well as about the roles and responsibilities of various performers of agricultural research. Let me emphasize that basic research relevant to the agricultural sector has been, and continues to be, largely the responsibility of public universities and USDA research laboratories. On the other hand, applied research which leads to products is largely done in the private sector where companies are able to capture the benefits from this type of product oriented research and thus realize a return on their investment. However, other kinds of applied research are being done in our State Agricultural Experiment Stations to lower the cost of production and to develop production systems which are critical for the future competitiveness of crop and livestock producers. Private firms cannot capture sufficient benefits from this kind of research and development to justify their investment.

Furthermore, very little private sector research is allocated to the development of new technology for specific agro-ecosystems within our various states. It is impossible for farmers alone to support agricultural research and development because their individual operations are not large enough to capture the benefits from effective, separate research and development programs. Public support for such cost cutting and competitiveness enhancing research is essential.

To further enhance the research at our Indiana Agricultural Experiment Station, currently supported by Hatch Act funds and funds from the State of Indiana, we focused on four primary thrusts in our recent state legislative request: (1) innovative new products, (2) reduce production costs for farmers, (3) assurance of a safe dependable food supply for consumers, and (4) revenue producing export products for the State of Indiana. The point I wish to make here is that there exists a continuing need for the support of several kinds of research and secondly that a mix of funding mechanisms can provide for optimum efficiency in the research and development process.

The base program in the State Agricultural Experiment Stations is the program of on-going research jointly funded by state appropriations and federal formula funds (Hatch and McIntire Stennis). Copies of a recent ESCOP publication "Research Dynamics - The Base Program of Research in the State Agricultural Experiment Stations" will be provided to all members of this distinguished Committee. That publication

provides evidence that the base program in the State Agricultural Experiment Stations is comprised of a series of specific and manageable research projects which is organized to address research of a fundamental nature critical to the future competitiveness of American agriculture. More directly however, that base program provides research on issues such as enhancing the profitability of agriculture, improving the use of natural resources, and maintaining a high quality, safe and affordable U.S. food supply.

As problems in agriculture have grown more complex, so has the science on which agricultural research is based. Thus, today much more of the total effort in the AES is directed at multidisciplinary research; and this research is more complex, more expensive and requires continuity of support.

It is in fact that very base of support which has provided the infrastructure in terms of a research system that is now poised and able to capitalize on the type of initiative proposed in this Senate Bill 970. More targeted funding by means of special grants and competitive grants under PL 89-106 enable our powerful agricultural research system to respond to special initiatives which warrant extra funding thrusts, which usually spring from this dynamic based program.

SPECIFIC COMMENTS ON SENATE BILL 970

At this time I will turn my attention to some specific comments on this particular Bill. We enthusiastically endorse the concept of support for the kind of research encompassed in this Bill. The success and efficiency of operation of the process will depend in large measure on the New Products Research Board called for in the Bill. The establishment in the Department of Agriculture of the New Products Research Board to be administered by the Assistant Secretary for Science and Education is an excellent approach. We recommend that this Board be very carefully chosen to have impeccable credentials in science and technology, and that they be individuals who are knowledgeable of the potential key areas and researchable problems that will lead to new agricultural research products of significance. This Board should have the flexibility to operate under rather general policy statements so that they can coordinate the overall program in the most efficient way and incorporate changes from time to time which are appropriate. We urge that this Board appoint representatives from relevant private industry to one or more of the committees of technical experts they establish to advise them.

While emphasis is proposed to be on the modification of plants to produce new marketable industrial or commercial products, I urge you not to overlook research to develop (a) new uses for existing crops which can be produced in the U.S. at relatively low and competitive unit cost of production and (b) to

engage in further development which will enhance the market potential for existing products. Also, we believe it is important to point out that we do not have all the basic information on plant genetics and biology to achieve the goals of this Act. Basic research is the lifeblood of new technology. From it will spring ideas for new products, new crops, and new processing procedures that can expand uses for agricultural commodities currently in surplus. Many believe that the payoff and flow of ideas from such basic research will be improved if it is focused on industrially relevant problems. In fact, as we visit with corporate research leaders, we find that they sometimes criticize university research because it does not include enough basic research which is sufficiently oriented toward solving industrial problems. I believe that at least part of our university basic research must be industrially targeted if it is to make its fullest contribution to developing new products and uses for surplus commodities. This Bill recognizes that need and provides a mechanism whereby the industrial relevance of basic research can be assured.

The Bill also emphasizes biotechnology. Certainly developments in biotechnology offer powerful new research tools that should be used to develop new uses and new products wherever those tools are most appropriate. At the same time, we urge that the emphasis be placed on research which will achieve the desired end product regardless of the type of tools needed for a particular study. Thus, for example, you may wish to consider a change in sub-point one "Purpose" at the top of page eight such that it would state: "Funding shall only be provided under this act to those projects that have as the principal purpose the development of new products." In that way the Board could clearly implement your purpose and insure that the best research projects were funded regardless of the type of tools to be used.

You have wisely recognized that a multi-stage review process should be followed. It is essential that the New Products Research Board have the responsibility to appoint review committees to examine the merits of specific research proposals that have been solicited by the Secretary. This allows the first level of review to involve expert panels to identify technical excellence in the proposals and to determine the merits of the proposals received in response to a request for proposals.

The criteria you have listed for selecting research projects are meritorious and appropriate. In my judgment, however, the Board should be allowed some latitude because one cannot predict the outcome of research. Often unexpected results and findings prove more valuable than what may have been anticipated ahead of time. There are cases through the history of science which indicate that many of our greatest

advances have in fact been somewhat serendipitous. I would add, however, that it is serendipity resulting from the mind and effort of creative and productive scientists.

You are to be commended for recommending that the consortia concept be fostered through this research funding act. Consortia involving public and private colleges and universities, private research operations, State Agricultural Experiment Stations and federal research laboratories should be able to bring to bear the necessary scientific talent to develop new products and new uses which will enhance the competitiveness of U.S. agriculture. Much of this is already being done through regional research projects of the State Agricultural Experiment Station system, and let me assure you that that system is encouraging this type of interaction. It also is important to encourage industrial research scientists and laboratories to become associated with the consortia. They can advise on the kinds of basic research to be funded for the public sector. Then they can become partners in some of the applied research which follows. University-Industry consortia offer an excellent vehicle for this involvement. Industry is then poised to proceed with the final applied research and development thrusts to speed adoption and improve payoffs.

Finally, I and my colleagues from Purdue University wish to compliment you on the accurate perception that research such as you are suggesting with this Bill must have a long-term commitment if it is to have any realistic prospects for success. Also, you have accurately recognized that such projects will require a focused, substantial investment instead of a large number of very small projects. I believe both of these concepts represent realistic perspectives.

Thank you for this opportunity to speak in support of this important proposed legislation. I would be pleased to respond to your questions.

**STATEMENT OF DANIEL J. ZAFFARANO
VICE PRESIDENT FOR RESEARCH, IOWA STATE UNIVERSITY**

Mr. Chairman, my name is Daniel Zaffarano and I serve as the Vice President for Research at Iowa State University. I am happy to be here today to support the proposed Alternative Agricultural Products Act of 1987.

As the land-grant university for the State, Iowa State University has been attempting to perform its role of creator and communicator of new agricultural knowledge in the midst of an economic and social crisis in the agricultural enterprise. This economic and social upheaval has resulted from several factors, including productivity increases, over-capitalization, international competition, and in my opinion, insufficient diversification.

While it is certainly true that the knowledge created at universities has contributed to the problem of over production and to some extent the lack of diversification, it is also true that such knowledge was and is responsible for the overall success of American agriculture. Increases in the production of most traditional American agricultural plants have brought us to the point where the American agricultural system is replacing land and labor with technology in agricultural production. This replacement of land and labor inputs by technology inputs in the production of almost everything has been standard economic behavior for decades. In agriculture it has been particularly apparent. Today we can produce ever-increasing quantities of corn, soybeans, wheat or any other basic commodity with less land and less labor. This is a reality of natural economic forces, it cannot be avoided and it should not be slowed down.

Research directed toward continued productivity increases in traditional agricultural commodities is a necessity if we hope to remain competitive in the world market. Furthermore, productivity increases imply continued efficiencies in the agricultural enterprise, assuring a low cost, high quality food supply for our nation and the world. Perhaps someday farmers in Iowa and the Midwest will produce corn at the rate of 250-300 bushels per acre. Such efficiencies are possible if we extrapolate present technology and offer a means for the development of lower-cost food for much of the world.

With such developments however there is one continuing and nagging problem: How do we best utilize the massive natural factory and highly skilled labor force for plant growth with which this nation has been endowed?

The answer from our perspective is simple and again comes from basic economics. Competition for the productive capacity of the natural factory is needed. We need competition for the productive space from plants that will serve as feedstocks for new foods and new industrial materials. At present we generally have only two or three major field crops in any particular region of the country. These crops, developed and grown over long periods of time, have become parts of the culture of various areas of the country and as such have taken on a dominant role in the regional economies and in regional thinking. The result has been that most financial investment, research and production has been directed toward these basic crops. Movement to new or modified crops, lacking an R&D base and lacking any understanding of the potential market, has been very difficult. Yet, research in the U.S., Canada and other nations is expanding in this area. There is however, a general lack of mission purpose and adequate funding to develop competing plants that may lead to new products and new markets for agriculture.

The program proposed in S. 970 provides a starting point for the development of an expanded agricultural research enterprise. We in the university community need the resources to expand our research beyond basic

soil science and basic commodities. From this perspective such a program should not be viewed not as a replacement for existing R&D programs. On the contrary, that research must continue so that the production efficiencies of basic commodities can be maximized. It is beyond this research that additional funding and programs are needed so as to stimulate new plant and new product development.

The development of new or modified plants for the production of new commercial products will require a large scale, multi-university, multi-year funding program. There are many questions regarding the fundamental biology of plants that need to be addressed as a part of this program and such questions require the funding characteristics described above.

Specifically, our recommendations regarding S. 970 include:

- 1) Multi-university consortia working with industry should be encouraged as a means of linking agricultural research schools with other efforts in molecular biology. Such a coordinated effort could enhance both our potential for technical success in developing new plants or new plant knowledge, but also in potentially developing subsequent products in the U.S.
- 2) The program should be designed to complement, not replace or jeopardize existing research efforts related to traditional commodities and their product uses.
- 3) Funding for research efforts should be multi-year in character because of the time required for this type of research.
- 4) The interagency review board is an excellent idea and should be maintained in the bill.
- 5) The expectations for plant development set out in the bill should be realistic and flexible. We don't know how long this R&D will take for any given plant.
- 6) There are many unanswered questions about plants. For example, we don't yet fully understand how plants deal with a stressful environment, how they regulate growth and development, or how we can improve the natural photosynthesis process. The point here is that very basic questions must be answered as a part of any effort to develop new plants for new products.

Again, we endorse S. 970 and urge the Congress to stimulate plant sciences research so that new plants and new products can expand, diversify, and stabilize our important agricultural economy.

TESTIMONY BY

DAVID L. ZARTMAN

PROFESSOR, THE OHIO STATE UNIVERSITY

BEFORE THE UNITED STATES SENATE COMMITTEE ON AGRICULTURE,

NUTRITION AND FORESTRY ALTERNATIVE AGRICULTURAL

PRODUCTS RESEARCH ACT OF 1987, SENATE BILL 970

WASHINGTON, D.C.

Chairman Leahy, Members of the Committee:

I want to thank you for this opportunity to present, on behalf of The Ohio State University and Land Grant Research Program conducted by the Agricultural Experiment Station in the United States, our testimony in favor of Senate Bill 970 to authorize a research program for the modification of plants and focusing on the development and production of new marketable industrial and commercial products.

Agriculture in the United States is experiencing economic distress. While the causes are many, one stands out. The capacity of Ohio and U. S. Agriculture to produce farm and forest products exceeds the domestic and export demand for farm and forest products at current prices and income level. Surplus production capability translates into lower farm prices, declining asset values, and lower tax revenues from the agricultural sector. A lesson from the history of U. S. Agriculture is that sustained prosperity is demand led.

With domestic demand for food essentially growing at the rate of population growth, with exports facing increase in competition, and with biotechnology promising to enhance substantially production capabilities, development of new non-food uses for farm and forest products appears to be an important (maybe the only) avenue for increasing demand for farm and forest products. In particular, there is an overwhelming need to divert a substantial amount of the capability for biotechnological research into the area of non-food uses for farm products. It is time for the nation to take a bold step in securing alternatives for farmers and foresters. A program to vigorously develop new uses will establish the United States of America as a leader in non-food product production from agricultural crops. Already the States have begun action to achieve this goal. I will outline some of these from the research program of the Ohio Agricultural Research and Development Center, the agricultural experiment station of The Ohio State University.

A novel anaerobic fermentation can produce acetic acid from carbohydrates with a yield higher than 90% compared to a 50% yield from conventional fermenting processes. By increasing the cell population in the reactor and removing the inhibitory fermentation

products, recent developments in immobilized cell reactor separation techniques have been able to increase the productivity of a fermentation process 10 times or greater than the conventional fermentation process. This will give the fermentation process a better competitive edge over synthetic processes. However, further work on the operational parameters and engineering design is necessary in order to scale up and evaluate the economic feasibility of these processes.

There are many high value specialty chemicals and biologically active compounds for which bio-process is either feasible or the only route to production. Sugars and starches, enzymes, bio-surfactants, vitamins, antibiotics and many other bio-polymers may be economically produced by microbial fermentation or culture of plant cells. Research is needed to explore the potential bio-process for producing the specialty compounds from agri-products.

Two of the possible products, acetic acid and ethanol, deserve further evaluation. If an effective and economic fermentation process is developed, chemicals from agricultural commodities can replace petroleum based chemicals. These technologically value added chemicals will create a new market, and additional favorable economic opportunities for agricultural commodities while alleviating U.S. dependency on petroleum. Acetic acid is one of the most important industrial chemicals used in the production of vinyl acetate, cellulose acetate, chloracetic acid and various acetate esters which are raw materials for production of numerous plastics. The annual production of acetic acid in the U.S. is 2.8 billion pounds, which was valued at \$1 billion in 1985. Acetic acid is almost exclusively produced from petroleum based hydrocarbons by chemical synthetic processes. Acetic acid is also produced from ethanol, from carbohydrates such as starch and sugar of agricultural commodities by fermentation. However, the acetic acid from agricultural products by conventional vinegar fermentation cannot economically compete today with the acetic acid from the synthetic process due to low production yield and high production cost. The acetic acid produced by fermentation is almost exclusively used for food rather than industrial chemical purposes.

There is new interest in production of acetic acid from agricultural commodities or industrial chemical purposes by anaerobic fermentation instead of the conventional aerobic fermentation. This novel fermentation process can convert 90% of the carbohydrate to acetic acid instead of less than 50% by conventional fermentation methods. The production of 2.8 billion pounds of acetic acid by the anaerobic fermentation process will require 3.1 billion pounds of corn starch or other fermentable carbohydrates which is equivalent to 20-60 billion pounds of the agricultural commodities depending upon the carbohydrate content in the commodities. Minimally, this is equivalent to fourteen million acres of corn.

Ethanol can readily be produced from many biological materials containing fermentable carbohydrates, such as starch and sugars. It is a proven, relatively inexpensive, environmentally safe octane enhancer. We want to reinforce the positive consideration

for research activity in this area. Ethanol production from corn has been averaging about 600 million gallons of ethanol per year requiring approximately 240 million bushels of corn. As the lead phase-out continues, it is expected that by mid-1990, 2.2 billion gallons of ethanol equivalent could be produced requiring about 1 billion bushels of corn. Corn is our most important, readily harvestable, renewable resource. Research efforts could lead to even more significant uses of ethanol in our replacement fuel programs and result in the diversion of 2 billion bushels of corn. Certainly this is worthy of a bold research effort. The Senate Bill 970 provides the basis for funding that research.

A story of what might happen is best described in the recent developments in the alternate uses for agricultural products for bio-medical and medical use. The objective there is to produce proteins of special economic, industrial or bio-medical value through the natural protein synthetic capacity of various animal organs such as the mammary gland or the oviduct of chickens as an alternative to production of these proteins through more costly industrial fermentation.

The concept of using recombinant proteins for bio-medical purposes through milk production and egg production arose in the United States, but is receiving strong attention in other countries of the world wherein their scientists also realize the potential for this technology. When first proposed (now over three years ago), this concept was received as unlikely scientific conjecture. Now, however, while it receives little support in the United States, it is receiving active attention from biotechnology groups in Australia, France, and The United Kingdom. It is now clear that we can produce livestock with various recombinant genes, but we have not done so for dairy cattle yet in the U.S. However, the British researchers have done so for dairy goats. Their advanced position is attested to in a symposium presentation scheduled for July 2, 1987 in London. The presentation is by J. Clark and P. Simons of AFRC Animal Breeding Research Organization of Edinburgh, Scotland titled "Milk as a Source of Transgene Products". Efforts to generate sufficient funding for aggressive research of this kind of "molecular farming" has not resulted in realistic funding to permit a competitive research position for U.S. scientists who originated the concept. Again, Ohio has research groups in three major Universities focused in this area with gene targets identified and gene insertion strategies being explored.

As a major public university, we enjoy an historic partnership with the federal government through the Hatch Act and its competitive grants programs.

Mr. Chairman, we want to assure you that we look upon the research opportunities of this Bill to be equally supportive of that long-time partnership and that the scientific faculties for research in these areas are geared up and ready to perform in what we hope will be historic development of new uses of crops, oils, and bio-medically useful proteins.

Thank you very much.

[Material submitted for inclusion in the record follows:]

QUESTIONS SUBMITTED BY SENATOR HARKIN

Industry

- 1) Can we reasonably expect any profit making company to take basic research results and try to make use of it in a direction that is highly risky and where the results will not be known for 10 or 15 years?
- 2) Please describe the type of basic and applied knowledge most needed by your industries to move us towards the expansion of additional uses of plants and plant materials?
- 3) What is your estimation of the need for expanded government participation in this applied research?
- 4) What is the potential of plant biotechnology as a stimulant of new economic activity?
- 5) What is the feasibility of developing new or modified plants that could lead to totally new products? What are the principal barriers?
- 6) To what extent are genetic modifications possible with well developed crops such as corn and soybeans to make useful products other than food.



PIONEER HI-BRED INTERNATIONAL, INC.
PLANT BREEDING DIVISION

BOX 85 • JOHNSTON, IOWA 50131-0085 • PHONE (515) DES MOINES 270-3300
CABLE PIOSEED DES MOINES • TELEX NO. 478-327

June 8, 1987

The Honorable Patrick Leahy, Chairman
United States Senate
Committee on Agriculture, Nutrition, and Forestry
Washington, DC 20510

Dear Senator Leahy:

Attached are answers to questions submitted by Senator Tom Harkin from the committee hearing held on the 15th, 1987, on S. 970, Alternative Agricultural Products Research Act of 1987.

Sincerely,

Nicholas M. Frey

Nicholas M. Frey
Group Director for Biotechnology Research

Enc.

NMF/kd

Question 1 - It is unlikely that industry will pursue very many research and development efforts that are highly risky and where results will not be known for ten to fifteen years. There may be exceptions, but those exceptions would be few in number. Industry will not carry out research of the scope and scale that S. 970 would support.

Question 2 - The type of basic and applied knowledge most needed by the seed industry, in order for us to expand additional uses of plants and plant materials, would be plant biochemistry and the genetic control of biochemical pathways in the plant. Biochemistry knowledge is important if we are to identify new plant products or modify existing plant products for new uses. If we know the biochemistry critical to the development of a product, then it can be determined if that process can be modified genetically. Alternatively, a product might be developed by modifying post-harvest processing of plant materials. This could be through microbial fermentation or alteration of the product through chemical processing. At this time, we may be more limited by our lack of basic knowledge than applied; but if basic knowledge is to be transferred into useful new products, it must be coupled with applied researchers who are attempting to fulfill a market need or to develop a market opportunity.

Question 3 - I feel that it is critical for the government to expand its participation in what I would call mission oriented research to develop new nonfood and nonfeed uses for agricultural produce that will ultimately increase the demand for agricultural products. I have used mission oriented research rather than applied research because too many people associate applied research with the kinds of research industry may be well suited to carry out. Mission oriented research can have both applied and basic components, and I think multidisciplinary research teams will be needed to pursue the development of new crops or new uses for existing crops. I think it is important for the government to support research that is high risk and long term in nature, and of great potential value to our society and economy. S. 970 will support that kind of research initiative.

Question 4 - I believe there is good potential for plant biotechnology to stimulate new economic development. If this research leads to the development of a new nonfood and nonfeed crop or crop use, it will not only increase demand for agricultural produce and thereby stimulate the agricultural economy, but it will also stimulate the development or expansion of plant processing businesses. Economic impacts will extend well beyond the farmer produce.

Question 5 - The technology that is available today makes it feasible to develop new or modified plants that could lead to totally new products. We are now capable of studying genetic controls of biological processes and modifying those controls to produce more of a given gene product or to alter an existing biochemical pathway. Furthermore, totally new traits can be added to crop plants by taking genes from other plants, microbes or, if appropriate, animals. As oil prices rise, the economic barriers that may now exist for certain nonfood and nonfeed uses of crops will be lower. This combination of lower economic and technical barriers makes this proposed legislation timely.

There do remain technical problems or limitations to be overcome, and assembling a series of technologies in order to successfully develop a new nonfood or nonfeed use for agricultural produce will be a challenging research problem. It is that challenge, however, that S.970 addresses. The research funding that this bill will provide can allow multidisciplinary research teams to begin assembling new emerging and existing technologies to develop useful products.

Question 6 - I personally feel it will be easier to modify developed crops such as corn and soybeans to make useful products other than food than it will be to develop and domesticate totally new crops. Furthermore, it may be possible to modify processing methods to convert existing crops into new products with nonfood uses. These accomplishments may require additional basic research on such things as starch synthesis and modification and oil synthesis and modification. These two molecules will likely provide the carbon skeletons that will be vital to nonfood or nonfeed uses of agricultural produce. Expanding our knowledge through research on starches and oils as well as proteins should be high priorities for research support under S. 970.



**Industrial
Biotechnology
Association**

1625 K Street, N.W.
Suite 1100
Washington, D.C. 20006
(202) 857-0244
FAX: (202) 857-0237

Richard D. Godown
President

Senator Patrick Leahy
Chairman
Committee on Agriculture, Nutrition,
and Forestry
United States Senate
627 Dirksen Senate Office Building
Washington, DC 20510-6000

Dear Senator Leahy:

Enclosed are answers to questions passed by Senator Tom Harkin regarding the recent hearings on S. 970 that were held on May 15. IBA hopes that these responses will substantively add to the record. The Association stands ready to offer its assistance as this legislation progresses.

1) Many industrial companies engage in intramural and intermural exploratory research and development programs. Companies continually reevaluate research and development programs to assess progress in product development. Although this time frame is important it is difficult to predict with accuracy. Many of the developments that have taken place in the biotechnology industry during the past five years were not predicted to occur until the 1990's. Clearly relying on predictions is problematic.

In the agricultural area much exploratory research is taking place within industry. Some of these results may never be commercialized, but there is the perception in the industrial sector that product developments in agricultural biotechnology will command significant market sales over the next twenty years.

2) One of the main reasons that plant biotechnology has not advanced as rapidly as the biomedical field is that far less is known about plant molecular genetics as compared to the microbial field. In addition, we do not have many transformation systems that can be used to genetically modify important crop plants. Both of these areas are in need of further research support.

It is difficult to assess what types of applied research are necessary at this point. Some uses of plant products are limited because of cost competition from the petrochemical industry. Certainly excess corn production can be used to produce a variety of chemicals via fermentation. Unfortunately these production routes are at present not economically competitive. Chief roadblocks in this area are in engineering, reactor design and product recovery.

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Karl H. Voepel,
Miles Laboratories, Inc.

June 4, 1987

Page Two

3) From our perspective it is unclear that there should be a major role for government in applied research. The government's chief role is to fund basic research and provide for the training of manpower.

4) The value of agricultural goods is estimated to be about \$150 billion per year. Advances in plant biotechnology can benefit the American farmer in two ways. First, they can lower the farmer's input costs thus increasing profitability. This is important in light of the present world market in agricultural goods. Reducing input costs will make the U.S. farm system the low cost producer of commodity farm products and thus encourage exports in this area.

Secondly, research is progressing in putting biotechnology to work in developing new crop species or higher value added products such as specialty oils.

5) Two major areas of research can lead to the development of new or modified plants that can result in new products. First, is the development of improved cultivars of existing plants that are acclimated to specific geographic regions in the United States. This is being done in the case of certain specialty plants such as guayule that produces rubber. This desert shrub is being intensively investigated and has attracted industrial attention as a supplement for synthetic rubber production. Genetic technologies will be used to select superior cultivars.

More long term research is focused on transferring novel genes into plants. At present, scientists are only able to transfer limited amounts of genetic material into plants. One goal of this research is to be able to move genetic material that codes for a specific biosynthetic pathway for a chemical substances. This would permit plants to manufacture substances they normally would not. Several major scientific advances will need to be made before this is a reality. Progress in the understanding of plant genetics and transformation systems will be required.

6) At this point in time the major non-food use for corn is as a feedstock for fermentation activities (see response to question 2).

Very truly yours,



RDG/tsh

ARGONNE NATIONAL LABORATORY

9700 SOUTH CASS AVENUE, ARGONNE, ILLINOIS 60439

June 9, 1987

Senator Patrick Leahy, Chairman
United States Senate
Committee on Agriculture, Nutrition,
and Forestry
Washington, D.C. 20510-6000

Dear Senator Leahy:

Following are my responses to the questions posed in your memo of May 26, 1987 regarding testimony on S.970, the Alternative Agricultural Products Research Act of 1987.

1. Based on interviews, group discussions, and participation of some 50 companies in the Midwest Plant Biotechnology Consortium, we believe that the answer to this question is a qualified "no". It is our sense that profit making companies, involved in a wide range of potential applications for plant biotechnology, will invest in high-risk research once they can clearly see possibilities for products within a five year span.
2. Attached is the Proceedings of a workshop held by the Midwest Plant Biotechnology Consortium in December of 1985. It provides a systematized description of the sorts of basic and applied research needed to speed the development of commercial products/processes for industries representative of many aspects of agriculture, agribusiness, and potential users of agricultural materials. There is much that we need to know about the chemistry, genetics, and physiology of plants. We also require basic information on plant materials; their chemistry, how they might be degraded (biologically or chemically) into materials that might be of greater industrial importance, and how compounds of potential commercial value derived from plants and/or the degradation of plant materials might be separated and purified economically to desired products.
3. There is presently some \$275M/yr. going into various aspects of plant research in the United States. I have heard it said that some \$20-30M of this total goes into research in plant biotechnology (defined here as the blend of genetics, biochemistry, physiology, etc., loosely based on the ability to transfer genetic materials across species/cultivar lines, that is most likely to result in new biological capabilities and thus new products and processes from plant materials). We believe, based upon our experience within the Midwest Plant Biotechnology Consortium, that our midwestern university and research institute members could effectively develop some \$24M/yr. in new research programs over the next two years. These would be programs that have been reviewed by cognizant industries, and that are considered best bets to lead to specific new products and processes.

U.S. DEPARTMENT of Energy

The University of Chicago

Senator Partick Leahy
Page 2
June 9, 1987

Based solely on our experience, a national program might require \$70-100M/yr. This would result in a total budget in plant sciences of some \$350-375M/yr.; much money but still a small percent (perhaps 10-20) of the federal funds that have made American medical research the base of the exceeding strong and successful American medical instrumentation and pharmaceutical industry.

Our experience suggests that this increase in funds should be used primarily for direct research costs; in particular in graduate and post-graduate training. We believe that some 10-15% of the funding total, assuming \$350-375M/yr. needs to be used for equipment and facilities development.

4. This is a difficult question to answer. We feel that plant biotechnology can lead to increased economic flexibility for farmers, e.g., they can grow specific crops for specific economic niches in industries beyond traditional food and fiber. That is an obvious economic stimulant. We sense that plant biotechnology might decrease the costs associated with pest control and fertilizers, thus, also decreasing the environmental and/or control costs associated with present agricultural practices. This may allow traditional plant materials to be used for new purposes. Plant materials may supplant more traditional feedstocks (e.g., petroleum) for fuels, chemicals, and pharmaceuticals. As the price and availability of such feedstocks change, one can clearly see economic benefit.

One may well ask what all of the above might mean in dollars. First, one might note that the most economically beneficial uses of new technologies are seldom what their originators expected. For example, for many years the most economically important use of lasers was in price and inventory control at supermarkets; not exactly an expected use. We would expect the same sorts of economic surprises to occur in this field. Second, economists have had some difficulty in precisely estimating the contribution of biotechnology in general to the U.S. and World economies. Figures range from billions of dollars per year to tens of billions and up. Given the lack of information, the inconsistency in assumptions used in such analyses, and our inability to predict potential utility, these sorts of economic discrepancies should not be too surprising.

5. Given time, the proper research and development programs, and the ability to transfer new knowledge from federally funded programs at research institutes and universities to industry, we would see the feasibility of new economically important crops as high. The principal barrier to such development is lack of knowledge. That translates into a need for properly targeted research funds.
6. Our answer to question (5) is, we believe, also appropriate for this question.

Sincerely,



Harvey Drucker
Chairman
Midwest Plant Biotechnology Consortium

QUESTIONS SUBMITTED BY SENATOR HARKIN

University Panel

- 1) What do you see as the role of the university in a "crash" plant biotechnology research initiative?
- 2) What are the barriers to multi-university research, linking ag. schools with others, in the area of plant biotechnology and subsequent new product development?
- 3) What is the potential for plant biotechnology R&D to contribute to agricultural diversification?
- 4) Are you aware of major plant biotechnology R&D initiatives outside of the U.S.? Please describe them.
- 5) To what extent are genetic modifications possible with well developed crops such as corn and soybeans to make useful products other than food.
- 6) Could you describe the current biotech research initiative at your institution? Why have the state and the university launched this effort?

IOWA STATE
UNIVERSITY

Vice President for Research
Dean, The Graduate College
201 Beardshear Hall
Ames, Iowa 50011
Telephone (515) 294-4531

June 2, 1987

Senator Patrick Leahy, Chairman
Committee on Agriculture, Nutrition
and Forestry
United States Senate
Washington, D.C. 20510-6000

Dear Senator Leahy:

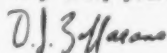
The answers to questions submitted by Senator Tom Harkin from the viewpoint of Iowa State University are as follows:

- 1) I firmly believe that the role of the University in biotechnology is to develop the most basic scientific understanding of the molecular, cellular, and developmental biology involved in living matter. The primary role of industry is to develop new products, using basic knowledge provided, in part, by universities.
- 2) There are few barriers to multiuniversity research, excluding the usual difficulties of travel and communication.
- 3) We think that plant biotechnology research is a major hope for promoting agricultural diversification. Through "gene splicing" we should be able to develop new and useful products.
- 4) My principal information is on biotechnology in Japan. The Japanese have specialized in developing fermentation procedures for producing biochemicals. Their special expertise with bacteria have resulted in a production plant for lysine now built in Iowa. This company produces an essential amino acid from bacteria fed with corn syrup. In principle, one could produce all of the essential amino acids using different strains of bacteria in this way.
- 5) Genetic modifications are certainly possible with crops such as corn, soybeans, and tobacco. Historically, tobacco has probably been more studied in terms of its potential to become a "host crop" from which biochemicals could be produced and extracted through genetic modification. New oils have already been produced from soybeans. These oils are not food products, and may be useful in industry.
- 6) The current biotech initiative at our institution is funded by the State of Iowa in the amount of \$17 million over a period of four

Senator Patrick Leahy
Page 2.
June 2, 1987

years. We have benefited from the advice of a committee of industrial scientists who have suggested that the best contribution the university could make to the welfare of their companies would be to strengthen basic research in biotechnology. With state support we are hiring new faculty members trained in the latest procedures of molecular biology, and are providing initial operating and setup expenses for new faculty in relevant fields. The biotechnology effort on this campus is guided by a faculty committee of nine people who are productive researchers in the life sciences.

Very truly yours,



D. J. Zaffarano
Vice President and Dean

DJZ/bg

PURDUE UNIVERSITY



AGRICULTURAL RESEARCH

June 10, 1987

Senator Patrick Leahy, Chairman
Committee on Agriculture, Nutrition
and Forestry
United States Senate
Washington, D.C. 20510-6000

Dear Senator Leahy:

Please find enclosed my written responses to Senator Harkin's questions regarding S. 970 (Alternative Agricultural Products Research Act of 1987). If you have any questions, please do not hesitate to contact me.

Sincerely yours,

A handwritten signature in dark ink, appearing to read "B. R. Baumgardt".

B. R. Baumgardt
Director

BRB:th



AGRICULTURE

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WRITTEN RESPONSES TO QUESTIONS ON S. 970

1. What do you see as the role of the university in a "crash" plant biotechnology research initiative?

The role of the university in a "crash" plant biotechnology research initiative is to carry out the fundamental basic research which is needed to lay the foundation for the development of new agricultural products, markets, and applications. The university is the only institution in our society with the capability and mission of carrying out the fundamental research which can benefit the American agricultural enterprise as a whole. Building upon these basic university-based discoveries, private industry will be able to carry out the development work for the proprietary applications which will benefit the U.S. economy and maintain U.S. competitiveness in world agribusiness markets.

The university today plays a critical role in bringing molecular biologists with their knowledge of new biotechnological techniques together with traditional plant scientists with their knowledge of plants, in order that together they can create the next technological revolution in agriculture. It is only through this kind of interdisciplinary, fundamental research that the advances needed by American agriculture and agribusiness will be able to be achieved.

The university also plays a key role in training graduate students in the new biotechnologies through their participation in the research laboratories. These are the kinds of employees trained in these new technologies that are needed by American agribusiness.

2. What are the barriers to multi-university research, linking ag. schools with others, in the area of plant biotechnology and subsequent new product development?

The main barrier to multi-university research, linking agriculture schools with others, in the area of plant biotechnology and subsequent new product development is the lack of federal funding for R&D consortia in plant biotechnology. The R&D consortium brings together universities (both public and private), federal laboratories, and private industry in a collaborative effort for basic research, applications development, and technology transfer. This is the organizational mechanism needed in order to carry out the new product development that will keep U.S. agribusiness competitive in world markets. This kind of R&D consortium can ensure excellence in research, provides for close collaboration between molecular biologists and traditional plant breeders, and makes possible good communication and collaboration among university and federal laboratory scientists and industrial scientists.

The university-industry-federal laboratory R&D consortium essentially provides the critical and necessary environment for the rapid transfer of technology, containing as it does all of the elements needed for the whole R&D continuum--beginning with the basic research and moving to the rapid development and commercial exploitation of new agricultural biotechnologies.

Federal funding for aggressive and competitive plant biotechnology-based research initiatives like these is not currently available. Universities have the capability of carrying out basic research in plant biotechnology; industry has the capability of carrying out proprietary development work based on university and federal laboratory inventions; the federal government must fund the basic research and the organizational costs of the collaboration among these sectors.

3. What is the potential for plant biotechnology R&D to contribute to agricultural diversification?

Biotechnology can contribute to Ag diversification in three ways:

- (a) Allow development of crops not now grown in the cornbelt to be modified and adapted to cornbelt conditions.
- (b) Enable development of new processing technologies so that new products can be made from crops. This is not really diversification, at least not at farm level, but could significantly impact on crop agriculture.
- (c) Enable development of special purpose or special use tracks in existing crops. This could be the most effective form of diversification as new, very specific markets would exist for special types of crops. Since most production practices would remain unchanged from current practices, farmers would not need to invest in new machinery or technology to grow these special purpose crops.

4. Are you aware of major plant biotechnology R&D initiatives outside of the U.S.? Please describe them.

Several countries have major centers or companies that are pushing biotechnology. Japan is big into producing compounds using liquid cell cultures. They are moving rapidly into molecular biology of several crops with rice being the big one. In the last year, 4 different labs in Japan have reported the ability to regenerate the Japonica lines of rice from protoplasts. The Japanese government has declared biotechnology a national scientific and commercial goal. Japan's Ministry of Trade and Industry has established a consortium of 14 major Japanese companies that will cooperate with the government and

universities in developing biotechnology. The government has set aside \$100 million for that purpose. In addition, in 1982 Japanese companies spent more than \$200 million apiece in the biotechnology area. The Plant Breeding Institute in U.K. has a major effort in plant molecular biology--emphasis is on wheat (the most important crop of the world), and there are several companies that are initiating plant biotechnology thrusts such as British Petroleum Inc. The Max Planck Institute in Germany, University of Brussel in Belgium, the MOLBAS Research Group in The Netherlands, The Friedrich Miescher-Institute (somehow connected to Ciba-Geigy) in Basel Switzerland are major research centers where dozens of scientists are working on plant cell and molecular biology. There are several examples of U.S. companies being owned by foreign companies--both of which have major efforts in plant biotechnology, e.g. Zoecon owned by Sandoz of Switzerland. CSIRO in Australia in engineering lucerne (a forage legume) to have a better protein (contain higher levels of sulfur containing amino acids) so that wool production is enhanced in sheep grazing on this improved lucerne.

5. **To what extent are genetic modifications possible with well developed crops such as corn and soybeans to make useful products other than food.**

At present it is very difficult to genetically engineer the major crops of the world because of specific barriers that exist either in the transformation process or in regeneration. In the case of monocots (which include cereals and grasses such as corn) our inability to regenerate plants from single cells is the major barrier. In the case of soybeans, regeneration from single cells is also a problem, however, it may be possible to circumvent this barrier by utilizing a natural vector (*Agrobacterium*) to transform the plant. Progress using this approach is very promising. Another big problem in genetically engineering these and other plants is our ignorance about the genetics of various processes. This causes us to not know how to identify and then isolate genes that control various processes such as disease resistance, insect resistance, flowering, maturity, leaf shape, responses to light, flooding, etc. The making of other useful products is really hampered by this lack of fundamental information about biosynthetic pathways and their regulation. This research is also not forthcoming because of the limited numbers of scientists who are simply thinking about possible alternatives. Companies think about such things but academics tend to pursue the more straight-forward.

6. Could you describe the current biotech research initiative at your institution? Why have the state and the university launched this effort?

Biotechnology research at Purdue is focused on the basic research needed to improve plants and animals using these new techniques. Primary emphasis has been on plants. We have made significant efforts to develop cooperative research with industry and to assure that the basic research is aimed at solving industrially relevant problems. The State of Indiana through the Indiana Corporation for Science and Technology, has provided significant funding for this biotechnology effort. A plant biotechnology center has been established. Many of the early research efforts have already attracted industrial or Federal agency funding.

100TH CONGRESS
1ST SESSION

S. 970

To authorize a research program for the modification of plants focusing on the development and production of new marketable industrial and commercial products, and for other purposes.

IN THE SENATE OF THE UNITED STATES

APRIL 9 (legislative day, MARCH 30), 1987

Mr. HARKIN (for himself, Mr. LEAHY, Mr. LUGAR, and Mr. GLENN) introduced the following bill; which was read twice and referred to the Committee on Agriculture, Nutrition, and Forestry

A BILL

To authorize a research program for the modification of plants focusing on the development and production of new marketable industrial and commercial products, and for other purposes.

1 *Be it enacted by the Senate and House of Representa-*
2 *tives of the United States of America in Congress assembled,*

3 **SECTION 1. SHORT TITLE.**

4 This Act may be cited as the "Alternative Agricultural
5 Products Research Act of 1987".

6 **SEC. 2. PURPOSE.**

7 It is the purpose of this Act—

1 (1) to authorize research in modification of plants,
2 and associated research, in order to develop and
3 produce marketable products other than traditional food
4 and fiber products; and

5 (2) to establish an independent New Products Re-
6 search Board to advise the Assistant Secretary of Ag-
7 riculture for Science and Education, with respect to se-
8 lection criteria for, and scientific feasibility of, prospec-
9 tive research projects under this Act.

10 **SEC. 3. DEFINITIONS.**

11 As used in this Act:

12 (a) **ASSISTANT SECRETARY.**—The term “Assist-
13 ant Secretary” means the Assistant Secretary of Agri-
14 culture for Science and Education.

15 (b) **BIOTECHNOLOGICAL RESEARCH PROJECT.**—
16 The term “biotechnological research project” means a
17 project authorized and funded by the Secretary that is
18 directed toward the development of a marketable in-
19 dustrial or commercial product, other than a traditional
20 food and fiber product, through biotechnology or other
21 modification of a plant.

22 (c) **BOARD.**—The term “Board” means the New
23 Products Research Board established under section 4
24 of this Act.

1 (d) DEVELOPMENT.—The term “development”
2 means directed fundamental research and applied re-
3 search necessary to make a product available for the
4 marketplace, including necessary research on the plant,
5 modification of plant materials, new methods, if any,
6 needed to cultivate the plant, the commercial separa-
7 tion of the new product, and any research on the uses
8 of the new product.

9 (e) NEW PRODUCT.—The term “new product”
10 means an item developed through a biotechnological
11 research or a plant research project that is primarily
12 not food or fiber, including an item that exists but is
13 not commercially available from a plant.

14 (f) PLANT PRODUCT RESEARCH PROJECT.—The
15 term “plant product research project” means a project
16 authorized and funded by the Secretary that is directed
17 towards the development of a marketable industrial or
18 commercial product, other than a traditional food and
19 fiber product, through the modification of the product
20 of a plant.

21 (g) PROJECT.—The term “project” means a bio-
22 technological research project or a plant product re-
23 search project.

24 (h) SECRETARY.—The term “Secretary” means
25 the Secretary of Agriculture.

1 SEC. 4. NEW PRODUCTS RESEARCH BOARD.

2 (a) ESTABLISHMENT.—There is established in the De-
3 partment of Agriculture the New Products Research Board
4 to be administered by the Assistant Secretary.

5 (b) FUNCTIONS.—The Board shall advise the Secre-
6 tary—

7 (1) on specific targets of opportunity for research
8 that most closely meet the selection criteria required
9 for a project to be eligible for funding under this Act;

10 (2) on the composition of review committees to
11 examine the merits of specific proposals for research
12 projects that have been solicited by the Secretary;

13 (3) on recommendations for the funding of specific
14 proposals for research projects and

15 (4) concerning progress made in carrying out
16 projects that are currently being undertaken.

17 (c) MEMBERSHIP.—

18 (1) APPOINTMENT.—The Board shall consist of 6
19 members, of which—

20 (A) 2 members shall be appointed by the As-
21 sistant Secretary;

22 (B) 1 member shall be appointed by the Di-
23 rector of the National Science Foundation;

24 (C) 1 member shall be appointed by the Sec-
25 retary of Energy;

1 (D) 1 member shall be appointed by the Sec-
2 retary of Commerce; and

3 (E) 1 member shall be appointed by the Di-
4 rector of the Office of Technology Assessment.

5 (2) TERM OF SERVICE.—The term of a member
6 of the Board shall be at the discretion of the appointing
7 authority.

8 (3) VACANCIES.—A vacancy on the Board shall
9 be filled in the manner in which the original appoint-
10 ment was made.

11 (4) CHAIRMAN.—The Assistant Secretary shall
12 designate one of the members of the Board as Chair-
13 man of the Board.

14 (5) GOVERNMENT MEMBERS.—All members of
15 the Board who shall be officers or employees of the
16 United States Government who shall serve without ad-
17 ditional compensation.

18 (6) EXPENSES.—All members of the Board shall
19 be reimbursed for travel, subsistence, and other neces-
20 sary expenses incurred by them in the performance of
21 their duties.

22 (7) MEETINGS.—The Board shall meet at the call
23 of the Chairman or a majority of its members.

24 (d) PERSONNEL AND SERVICES.—The Board may ap-
25 point personnel and procure permanent, temporary, and

1 intermittent services as it considers necessary, under section
2 3109 of title 5, United States Code, at rates for individuals
3 that do not exceed the rate prescribed for GS-18 of the Gen-
4 eral Schedule under section 5332 of such title.

5 (e) EXPERTS.—The Board may establish committees of
6 technical experts to advise the Board on matters that are
7 determined to be appropriate by the Board.

8 (f) RULES AND REGULATIONS.—The Board is author-
9 ized to propose rules and regulations to the Secretary, and
10 may promulgate procedures that may be necessary to carry
11 out the functions of the Board.

12 (g) DEPARTMENT OF AGRICULTURE RESOURCES.—
13 The Board is authorized to utilize, with the consent of the
14 Secretary, the services, equipment, personnel, information,
15 and facilities of the Department of Agriculture, with or with-
16 out reimbursement therefore.

17 (h) HEARINGS.—The Board may, for the purpose of
18 carrying out this Act, hold such hearings, and sit and act at
19 such times and places, as the Board considers appropriate.

20 SEC. 5. RESEARCH PROJECTS.

21 (a) AUTHORIZATION.—The Secretary, on a recommen-
22 dation from the Board, shall select projects that are to re-
23 ceive funding under this Act, for purposes of research to de-
24 velop and produce new products.

25 (b) APPROPRIATE PROJECTS.—

1 (1) DEVELOPMENT.—Each project shall target
2 development of a new crop, or modification of an exist-
3 ing crop or crop material, that meets the criteria listed
4 in paragraph (2).

5 (2) CRITERIA.—Projects should be selected on
6 the basis of—

7 (A) the prospect of developing viable technol-
8 ogies that could make it possible to use or modify
9 existing plants or plant products to provide an
10 economically separable quantity of new products;

11 (B) the need for a new product of the type
12 contemplated;

13 (C) the potential market size of the new
14 product;

15 (D) the likely time period needed to bring the
16 new product into the stream of commerce for gen-
17 eral use;

18 (E) the likely impact on reducing Federal
19 crop subsidies and other government agricultural
20 assistance program costs;

21 (F) the ability to grow the plant used to
22 produce the new product at a profit; and

23 (G) the availability of the expertise and fa-
24 cilities required to conduct the proposed research.

25 (c) FUNDING.—

1 (1) PURPOSE.—Funding shall only be provided
2 under this Act to those projects that have as the prin-
3 cipal purpose the development of new products, with
4 priority given to biotechnological research projects, and
5 no less than one half of the appropriated funds being
6 allocated to biotechnological research projects.

7 (2) CONSORTIA.—Unless the Secretary finds it
8 appropriate for a single research entity to conduct a
9 project, each project shall be conducted by a project
10 group that may include a consortium of any of the
11 following—

12 (A) public and private colleges and univer-
13 sities;

14 (B) private research facilities and personnel;

15 (C) State agricultural experiment stations;

16 and

17 (D) Federal research laboratories.

18 (3) SECONDARY USES.—Funding shall not be
19 denied if paragraph (1) is satisfied even if the devel-
20 oped plant has a food or fiber use in addition to the use
21 described in paragraph (1).

22 (4) PERIOD OF FUNDING.—Funding—

23 (A) shall cover the proposed research neces-
24 sary for not less than 5 years, or until a market-

1 able product is developed or determined to be un-
2 attainable or unnecessary; and

3 (B) may be extended, subject to satisfactory
4 review, for additional 3 year periods or until a
5 marketable new product is developed or deter-
6 mined to be unattainable or unnecessary.

7 (5) NONTRADITIONAL FOOD AND FIBER USES.—

8 If the development of nontraditional food and fiber uses
9 becomes the principal likely result of a project, funding
10 may be continued if the project continues to meet the
11 criteria set forth in subsection (b)(2) with the exception
12 of criterion (A).

13 (6) NUMBER OF PROJECTS.—

14 (A) INITIAL PROJECTION.—The Secretary
15 shall fund not less than 15 projects within the 24-
16 month period beginning on the date of enactment
17 of this Act, with funding committed for at least 5
18 projects within the 12-month period beginning on
19 the date of enactment of this Act.

20 (B) ADJUSTMENT.—If the amount appropri-
21 ated under section 6 is reduced, the number of
22 new projects to be funded shall be reduced pro-
23 portionately

24 (d) CONTRACTS.—The Secretary may sign contracts
25 that assign research responsibilities to an appropriate consor-

1 tia capable of conducting the appropriate research over the
2 applicable research period.

3 (e) REVIEW AND REPORTING.—

4 (1) PROJECT GROUPS.—A project group shall
5 report, on the progress of the group, to the Board an-
6 nually or as otherwise required by the Board.

7 (2) THE BOARD.—The Board shall review the
8 progress of the projects approved by the Secretary, and
9 report to the Secretary on the projects with recommen-
10 dations concerning continued research.

11 SEC. 6. AUTHORIZATION OF APPROPRIATIONS.

12 To carry out this Act, there are authorized to be appro-
13 priated \$75,000,000 for the fiscal year 1988, and each of the
14 19 fiscal years thereafter.

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